(*Revised—Second Edition*)
—1953—

INDIAN CENTRAL COTTON COMMITTEE

MANURING OF COTTON IN INDIA

(A review of the results of cotton manurial trials carried out in India with suggestions for future experiments).

BY

V. G. PANSE.

(Statistical Adviser, Indian Council Of Agricultural Research, New-Delhi, & Ex-Director, Institute Of Plant Industry, Indore.)

Published by the Indian Central Cotton Committee, Bombay.

Price Rs. 5.

THE INDIAN CENTRAL COTTON COMMITTEE
INCORPORATED BY ACT XIV OF 1923.

MANURING
OF
COTTON IN INDIA

◆

V. G. PANSE.

PREFACE TO THE FIRST EDITION.

"A search for information on manuring of cotton from the various experimental farms elicits little beyond a belief that either compost or green manuring is essential to supplement the general deficiency in supplies of farmyard manure and that artificials are regarded with suspicion unless invariably combined with organic manures, usually in the form of oil cakes. Scant experimental confirmation of these beliefs is forthcoming", wrote Frank Crowther in his article entitled "Impressions of cotton growing in India by a visitor from Egypt and the Sudan" (Agriculture & Livestock, in India, Vol. IX, Part IV, 1939). Recognising the need for information on cotton manuring, the Indian Central Cotton Committee decided in 1940 that the data on manurial trials collected up to 1934 and in subsequent years, in so far as they related to cotton, should be examined and model lay-outs of manurial experiments designed for the consideration of the Committee. The work was entrusted to Dr. Panse, Statistician, Cotton Genetics Research Scheme, Indore. The present report was the outcome ; this was considered by the Committee at its meeting held in July 1942 and it was decided that a short article summarising the present position in regard to cotton manuring and indicating the lines for future work should be published in "Indian Farming" and the report itself as a bulletin of the Committee. The short article accordingly appeared in "Indian Farming," Vol. V. No. 3, March 1944.

The thanks of the Committee are due to Provincial and State Departments of Agriculture for their co-operation in making available the relevant data and for rendering all necessary assistance in the matter.

BOMBAY,
September, 1945.

D. N. MAHTA,
Secretary,
INDIAN CENTRAL COTTON COMMITTEE.

PREFACE TO THE SECOND EDITION.

With the partition of the country, and the consequent loss in cotton acreage and production, the need for increasing the yield of the crop, which is at present very low, has received great attention in recent years. The question of manuring cotton fields with artificial fertilizers or organic manures has been under investigation since a long time in the different States in the Indian Union. The data collected had been collated by Dr. Panse and published as a Bulletin of the Indian Central Cotton Committee in 1947. The information relating to certain other aspects of manuring was recently written up as an additional chapter of the previous Bulletin, and as the copies of the earlier edition had been exhausted, it was decided by the Committee in February, 1951, to issue a second edition of this publication. Though the manuring of cotton usually gives increased yield, it will be seen from the data presented in the revised edition that all soils in the different cotton tracts do not respond in a similar way to the application of any particular fertilizer or manure. It is the character and behaviour of each individual type of soil that seems to demand a critical examination before a programme of manuring is undertaken. As a general conclusion, Dr. Panse has stressed the need for nitrogenous manuring of cotton fields. However, to achieve the desired objective, it is necessary to give due consideration to the time of application and dose of manure, depending on the nature of the soil and the distribution of rainfall of the cotton area where such manurial treatment is undertaken.

It is hoped that the new edition will serve as a useful guide to scientific workers as well as farmers growing the crop in the fields.

BOMBAY,
March, 1953.

K. SAWHNEY,
Former Secretary,
INDIAN CENTRAL COTTON COMMITTEE
&
Agricultural Adviser,
Community Projects Administration (Planning Commission) Government of India, New Delhi.

CONTENTS

PAGES

CHAPTER I.

INTRODUCTION ... ... 1—4

CHAPTER II.

SUMMARY OF PROVINCIAL RESULTS AND CONCLUSIONS ... ... 5—17
(a) Provincial Results 5
(b) Conclusions ... ... 14—

CHAPTER III.

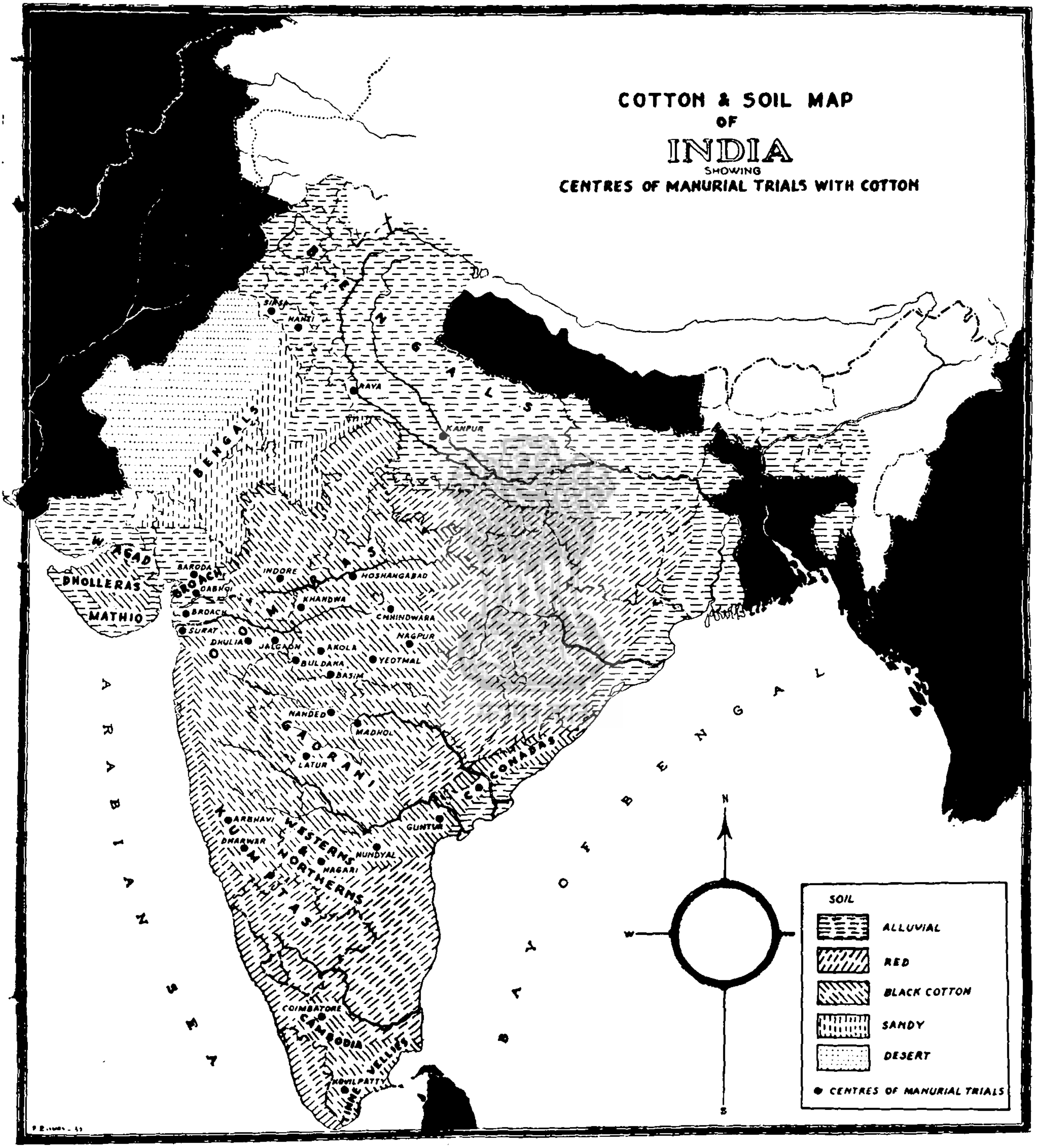
NITROGENOUS MANURING OF COTTON ... ... 18—35
(a) Economics of Manuring 18
(b) Optimum Conditions for Manuring ... ... 30—

CHAPTER IV.

PLANNING OF FUTURE EXPERIMENTAL WORK ... ... 36—41

CHAPTER V

NEW SERIES OF MANURIAL TRIALS ON RAIN FED COTTON ... ... 42—56
APPENDICES ... ... 57—80



COTTON & SOIL MAP OF INDIA SHOWING CENTRES OF MANURIAL TRIALS WITH COTTON

CHAPTER I.

INTRODUCTION.

The general level of yields of agricultural crops in India is low and cotton is not an exception. While accurate figures are not available the average yield of lint is most probably not greater than about 200 lbs. per acre for irrigated cotton and about 75 lbs. for rain-fed cotton. These estimates compare poorly with the reported yields of 450 lbs. per acre in Egypt and 350 lbs. in Sudan, in both of which countries cotton is grown under irrigation, while the average production per acre in the United States where cotton is not irrigated is as high as that of irrigated cotton in India. Cotton is grown over a large part of India and as a cash crop plays an important role in the economy of the Indian farmer. The need for increasing its yield is, therefore, obvious. This increase is likely to be brought about more easily by manuring than by attempting to breed higher yielding varieties. In the first place, improvement of quality is rightly considered to be the primary objective of the cotton breeder in India to-day, and if a simultaneous increase in yield is also sought, it will render his task more difficult. Secondly, only a small increase in yield may be reasonably expected through breeding, and though the grower will secure it without any cost to himself, this cannot provide the solution of the problem of poor yields.

This problem has always engaged the attention of the Indian Central Cotton Committee and the subject of manuring received a fresh impetus when, after a visit to India in 1937-38, Dr. F. Crowther published his impressions of cotton growing in India on the background of his experience in Egypt and Sudan (Crowther, 1939). The Committee discussed the subject in its meeting in January 1940, and decided that all available data on cotton manurial trials carried out in the past in different parts of India should be critically examined by a Statistician who should then prepare plans for future experimental work on the basis of the results of this examination. The idea was to evolve one or two standard experimental designs rather like those adopted by Crowther in his work in Egypt (1936), and use these for trials at a number of centres. The implication in the decision of the Committee, that past data were to be examined with the object of obtaining guidance in planning future manurial trials, rather than for making direct practical recommendations to farmers on the manuring of cotton, correctly indicates the best use that should be made of this material. Almost all trials in the past were confined to agricultural research stations and other Government farms, whose number is too small considering the vastness and heterogeneity of the area on which cotton is grown in India. The fertility of land and other agricultural conditions at these farms are also usually superior to those met with in the surrounding district. For these reasons, if any results suitable for immediate practical application emerge from the examination of past trials, their verification under cotton growers' conditions will still be necessary before they can be recommended for adoption.

Of the eleven provinces in British India, cotton is grown in six; besides these, it is also grown in Hyderabad State and in a smaller proportion in almost all States in Central India and Rajputana. A map of India is attached (Fig. 1) on which the different commercial varieties of cotton produced and the soil types on which they grow are shown. Centres at which cotton manurial trials were carried out are also marked in this map.

India may be divided into two main cotton tracts, (1) the Indo-Gangetic-alluvium and (2) peninsular India. Among centres for which results of manurial trials are available, those in the United Provinces, Punjab and Sind are included in the first tract and those in Bombay, Madras and Central Provinces and Indore in Central India are included in the second. In the first tract, both *desi** (*G. arboreum* var. *neglectum* forma *bengalensis*) and American (*G. hirsutum*), cottons are grown on irrigation, with the exception of a small proportion of *desi* grown on rain in the United Provinces and Punjab. Manurial trials were conducted on irrigated *desi* cotton in the United Provinces, and in the south-eastern part of Punjab at

---

* Indigenous

Hansi and Sirsa. The remaining trials in this tract were carried out on irrigated American cotton. In peninsular India, cotton is grown entirely on rain, except Cambodia (*G. hirsutum*) which is grown with irrigation on red soil in Coimbatore and Salem districts of Madras Province. Black cotton soil, a fairly heavy clay, is the principal soil type of this tract and the variety of cotton grown is a *desi* (*G. arboreum* var. *neglectum*). Another *desi* type (*G. herbaceum*) is grown on the coastal alluvium in Gujerat and in Dharwar district in Bombay Province. Farther south, mixtures of these two species in varying proportions are common in Madras Province. Since cotton cultivation in this tract is dependent on rainfall, the amount of rainfall is a factor of prime importance in determining the effect of manuring. For reference in the subsequent discussion, the mean annual rainfall at different stations in this tract is given below. These averages were calculated from the data made available, and the number of years on which they are based are shown in brackets.

TABLE I.

Mean annual rainfall (inches) at certain stations in peninsular India.

Bombay.		*Central Provinces.*	
Surat	38·9 (32)	Khandwa	35·6 (11)
Broach	26·8 (3)	Powarkhera	47·7 (40)
Jalgaon	29·7 (21)	Buldhana	37·1 (11)
Dhulia	20·3 (9)	Akola	29·8 (40)
Arbhavi	23·8 (22)	Yeotmal	37·0 (9)
Dharwar	28·0 (33)	Nagpur	48·1 (17)
Madras.		*Central India.*	
Hagari	20·3 (30)	Indore	38·1 (17)
Bellary	19·2 (8)		
Nandyal	28·0 (32)		
Guntur	33·0 (16)		
Coimbatore	24·8 (31)		
Koilpatti	29·2 (29)		

Manurial trials have been conducted in the past mostly by the provincial departments of agriculture. A certain number of trials were also carried out by the Imperial Chemical Industries (India) Ltd., and are included in the present report. In all, results of over 400 experiments were collected and examined. Their distribution provincewise is shown in Table II.

TABLE II.

Number of cotton manurial experiments examined.

Province.	DEPARTMENTAL		IMP. CHEM. IND.		Total
	Replicated	Unreplicated.	Replicated	Unreplicated.	
Bombay	89	26	5	...	120
Central Provinces	79	15	2	...	96
Indore	33	...	...	...	33
Madras	59	7	1	...	67
United Provinces	14	2	...	...	16
Punjab	55	2	19	4	80
Sind	...	...	12	...	12
	329	52	39	4	424

---

* Indigenous.

The earliest available data are for trials started during the years 1905 to 1908 in most provinces, except Punjab where cotton manurial trials were apparently begun only in 1919. The Indore trials were carried out at the Institute of Plant Industry and are of a very recent date. The only material from Sind that was found useful for the present analysis was from trials conducted by the Imperial Chemical Industries from 1934 onwards. The most recent trials included in the report are those carried out in the years 1937 to 1939 ; but in Punjab, results of manurial trials which formed part of the cotton physiological scheme financed by the Indian Central Cotton Committee were available upto the year 1941-42 and are taken into account.

The chief source of data for trials carried out till 1930-31 is the 'Report on the Analysis of Manurial Experiments in India' by Rao Bahadur M. Vaidyanathan, published by the Imperial Council of Agricultural Research in 1933. This is a very useful publication in that it contains a comprehensive list of the results of manurial trials on an all-India basis. In extracting information relating to cotton from this volume, however, a few serious errors were unfortunately discovered. Research workers who wish to use the material contained in the Report would, therefore, be well advised to check its accuracy from other sources. Additional details of experiments conducted in Bombay Province, during the period covered by this publication are given in 'Experiments in Manuring Crops in the Bombay Presidency, 1896—1931' by Rao Bahadur D. L. Sahasrabudhe. Results of later trials were obtained through correspondence with provincial officers or from published annual reports of experimental farms under the provincial departments of agriculture. A list of official publications which have been used as sources of experimental data has been appended (Appendix A).

For a correct appreciation of the results of an experiment it is necessary to have precise information of the conditions under which the experiment was performed. It was found that the recorded information was frequently incomplete or vague. A considerable amount of time and labour had, consequently to be spent in checking and completing the various details as far as it was possible. If published results of agricultural trials are to be put to the best use, it is important that they should include all relevant agricultural details such as the location, history and fertility of the experimental field, cultivation, irrigation, variety, etc., the exact nature of the layout, the number of replications and dimensions of plots, and numerical results of each plot in standard units, if possible, in addition to mean values for different treatments and their standard errors. The question of adopting a suitable standard form for presenting experimental results in annual reports deserves serious consideration at the hands of provincial agricultural departments.

The present report is divided into three sections. Results of manurial trials carried out at each experiment station are summarized province by province in the first section and the general conclusions derived from a careful inspection of these results are discussed at the end of this section. A further statistical analysis of the data was made with a view to study more critically certain important aspects of manuring. These include, the nature of the relationship between quantity of manure and increase in yield which forms the basis for studying the economics of manuring, and the influence of environmental conditions like soil fertility or rainfall on the response of cotton to manuring. A knowledge of the influence of such factors is essential for making recommendations on manuring more specific. Results of this analysis are described in the second section. The third section deals with suggestions, based on the examination of past data, for planning future experimental work on cotton manuring. It will be observed that trials on rain-fed cotton on the black soil were the most numerous among the past trials. More conclusive information on various points is thus available for unirrigated than for irrigated cotton. and consequently a programme of experimental work likely to lead more speedily to practical recommendations for the manuring of cotton in the unirrigated tract can be formulated. This is a fortunate circumstance, since it is also in the unirrigated tract that cotton yield is low and the problem of increasing it by manuring the most urgent..

Recent advances in statistical methods and in the subject of experimental design have brought about a revolutionary change in the place of the field trial in agricultural research. The field trial is no longer intended to demonstrate pre-existing ideas or theories of the experimenter and consequently laid out to suit this objective, but has now become a precise tool for research. In the language of mechanics, we may look upon the field experiment as a machine for turning out information. Just as the efficiency of a machine, or the ratio between the amount of energy used and the output of work, depends upon its construction, so does the efficiency of an experiment depend on its design. A great deal of thought is, therefore, now given to evolving experimental designs with a maximum efficiency, that is, capable of providing a maximum amount of information in relation to the amount of labour and time spent in carrying out the trial. Looked at from this point of view, the older manurial trials, which suffer from a lack of any planning or co-ordination, must be considered to have a poor efficiency. Their statistical examination is none the less important, because whatever information they supply is going to be of basic value in preparing future experimental programmes.

The task of examining such a heterogenous body of data is not simple. The straightforward statistical methods characteristic of modern layouts are usually inapplicable, and a rigorous statistical treatment of the data is frequently either impossible or not worth attempting because the time and labour needed are out of proportion to the practical objectives involved.

Statistical procedures employed in analysing the present data are indicated at the proper places in the report; but it is necessary to record here that the writer had the benefit of discussing the appropriateness and validity of different methods with Dr. F. Yates, Mr. D. J. Finney, and Dr. D. A. Boyd of Rothamsted Experiment Station, England, Dr. P. V. Sukhatme of the Imperial Council of Agricultural Research and Dr. R. J. Kalamkar of the Central Provinces Agricultural Department. To these persons the writer's heartfelt thanks are due. He is further indebted to Mr. Finney for carrying on the discussion in considerable detail through correspondence in the difficult conditions during the second World War.

The directors of agriculture and other officers of the provincial departments of agriculture extended their co-operation to the investigation by supplying the data and other information relating to manurial trials carried out in their provinces. Trials conducted by the Imperial Chemical Industries (India) are already referred to. The author's thanks are due to the Manager of the Company for making these results available and for permission to incorporate them in the report. Results of some of the most recent trials carried out in Punjab as part of the cotton physiological scheme of the Indian Central Cotton Committee were kindly supplied by Prof. R. H. Dastur and these have provided valuable information.

The collection and tabulation of data and much of the statistical analysis were done by Mr. V. B. Sghasrabudhe who was specially appointed for this purpose. Additional statistical analysis was carried out by Mr. G. R. Ayachit. Acknowledgment is due to both these persons for their assistance. The author wishes to express his thanks to Mr. K. Ramiah for his helpful suggestions during the preparation of the report. Messrs. V. B. Sahasrabuddhe and V. K. Mokashi gave assistance in the planning and analysis of the coordinated manurial trials on rainfed cotton described in chapter V.

A popular summary of the results of the present investigation was published in *Indian Farming* (Panse, V. G. 1944). A popular article on the results of the coordinated manurial trials on rainfed cotton was published in the Indian Cotton Growing Review.

REFERENCES

1. Crowther, F. ... ... (1939) *Agric. and Livestock in Ind.* 9, 401—417.

2. Crowther, F. ... ... (1936) *Tech. Bull. Roy. Agric. Soc., Egypt No.* 26, 1—47.
Tomforde Adolf, and Ahmed Mahmoud.

3. Panse, V. G. ... ... (1944) *Indian Farming*, *5*, 131—135.

CHAPTER II.

SUMMARY OF PROVINCIAL RESULTS AND CONCLUSIONS.

(*a*) PROVINCIAL RESULTS.

To determine the extra yield per acre secured by manuring is the chief object of manurial experiments. The first step in the analysis of the data was, therefore, to obtain from individual trials the best estimate of response to a given dose of manure together with the standard error of the response where possible. The standard error is a measure of the accuracy with which the response was experimentally determined and shows the degree of reliance to be placed on the numerical value of the response as being the result of a manurial treatment. To calculate the standard error a certain amount of fresh statistical analysis by more appropriate methods than those previously employed had to be carried out in some cases. Experiments repeated on the same set of plots in different seasons were treated as a single trial, as results obtained in different seasons cannot be considered independent. The responses from individual experiments were pooled together and the average response to each dose of manure with its standard error was worked out. For this purpose, the analysis of variance was applied where feasible, otherwise straight averages were taken. If more than one trial were carried out in the same season, the average response for the season was estimated first and these averages then pooled over different seasons. This procedure gave equal weight to results obtained in different seasons, and not to individual experiments irrespective of season.

For unreplicated trials the standard error of the response is not available. Apart from these, a number of other trials had only duplicate plots. Replication is generally inadequate in the past experiments and this has frequently resulted in high standard errors. In replicated trials, plots were invariably arranged systematically instead of at random. Randomness is essential for the strict validity of the statistical analysis and interpretation of results. In spite of these drawbacks, conclusions derived from a large number of trials are not likely to be seriously biased and should provide a very useful basis for designing future experiments.

A certain number of trials had to be omitted from the analysis, because estimation of response to manuring was not possible, in the absence of suitable control plots in the trial. Results from green manuring also could not be considered as information on the quantity of manure applied for its nitrogen content is lacking and a quantitative comparison with other manures is, therefore, not possible. In some other cases, the treatment combinations tested did not permit the isolation of the effects of individual manurial components. For example, the comparison of a mixture of ammonium sulphate and bonemeal with no-manure cannot show the separate contributions of nitrogen and phosphate to the manurial response and also does not answer the question whether the combination has any extra effect beyond that due to the individual constituents.

The average responses (increases in the yield of seed cotton in lbs. per acre) together with their standard errors are given for each station, province by province, in Tables I to VII in Appendix B. Responses from unreplicated trials are shown separately. No standard error can be attached to these, and the results serve as useful evidence only in conjunction with other trials. Results of trials conducted by the Imperial Chemical Industries are also separately recorded and marked with asterisks. For a comparison of responses to different doses of manure, artificial fertilizers, organic manures and mixtures of the two are grouped separately in the Tables. The responses are entered against the quantities of nitrogen (N), phosphate (P_2O_5) and potash (K_2O) in lbs. per acre applied in the form of artificials, and against the amounts of organic manures and their nitrogen equivalents per acre. Responses are over no-manure, except where it is stated otherwise in the remarks column.

Each Table consists of 12 columns, the first six of which deal with artificials and the remaining six with organics or mixtures of the two. The name of the station is given in column 1. In columns 2 and 7 the year in which the trial was carried out is recorded. Where more than one trial was carried out in the same year, the number is indicated in brackets against the year. The manurial content of artificial feritilizers is shown in column 3, and for organic manures the amount of manure applied per acre and its nitrogen equivalent are entered in columns 8 and 9. Where mixed manures are used their composition is shown under these columns. The response, its standard error and remarks are given in columns 4, 5 and 6 for artificials and 10, 11 and 12 for organics and mixtures. Results given in these Tables are briefly summarized below provincewise.

BOMBAY PROVINCE.

(TABLE I. APPENDIX B.)

Surat, Broach, Dabhoi.

These three stations are situated in Gujerat, the northern cotton tract of the province where the soil is alluvial and herbaceum cotton with a monopodial habit is grown. The plants develop into fairly large bushes and are late to mature.

An average increase of 207 lbs. of seed cotton per acre in yield was obtained by an application of 40 lbs. of nitrogen (200 lbs. ammonium sulphate) in two replicated trials conducted for six years at Surat. The response to 20 lbs. of nitrogen was half this quantity in the same trial.

Fertilizer applied one and a half month after sowing gave a higher increase than earlier application.

In the experiments conducted by the Imperial Chemical Industries at Surat, similar average responses to nitrogen were obtained, but in 1931 when two dates of application were compared, the whole application at sowing was found to give a significantly higher response than when half the fertilizer was applied six weeks later. Phosphate was without any benefit to the crop, sometimes even showing a tendency to depress yield at an increased rate of application. Among organic manures, very heavy doses of farmyard manure (up to 25 tons per acre, equivalent to 280 lbs. nitrogen) have been tried; but no appreciable responses were observed except when ten tons of farmyard manure was applied in trenches. Castor cake, crushed cotton seed or *neem* (margosa) seed also showed no effect.

At Dabhoi two trials were carried out by the Imperial Chemical Industries. While responses to nitrogen were similar to those at Surat, striking responses to phosphate applied singly or in conjunction with nitrogen, were obtained. Potash showed little effect.

Jalgaon, Dhulia.

These stations are located in the black soil tract in the central part of the province. The soil at Dhulia is lighter than at Jalgaon and the annual rainfall only 20 inches, which is over 9 inches less than at Jalgaon.

At Jalgaon there was an increasing response to increased quantities of nitrogen; but the highest does of nitrogen tried was only 24 lbs. per acre. For 20 lbs. of nitrogen there was an average increase of 124 lbs. per acre in yield; when similar quantities of nitrogen were applied in combination with 100 lbs. of castor cake or with 7½ tons of farmyard manure, the response to nitrogen was not affected by the cake but was distinctly reduced by the farmyard manure. Phosphate also appeared to have a depressing effect, as 20 lbs. nitrogen and 20 lbs. phosphate together gave only half the increase in yield obtained from 20 lbs. of nitrogen alone.

Thirty cartloads of night soil (approximately 252 lbs. nitrogen) gave an increase of 284 lbs. in yield. Castor cake (400 lbs.) had no effect.

The poor rainfall at Dhulia appears to be responsible for the depression in yield observed from the application of artificial fertilizers. Responses to heavy doses of farmyard manure in two unreplicated trials were also related to the annual rainfall.

Dharwar, Arbhavi.

The soils at these two stations on the border of the black soil tract in the south of the province are derived not from trap, which is the source of black soil, but from chlorites and mica schists. The cotton grown is herbaceum, but is less monopodial than in Gujerat and has a somewhat shorter growing period.

At Dharwar, there was no response to nitrogen, phosphate or potash applied in the form of artificial fertilizers or bonemeal. A combination of artificial nitrogen and farmyard manure was also not effective, except in one trial where 28 lbs. of nitrogen over a basal dressing of 2½ tons of farmyard manure produced an increase of 202 lbs. in yield after the preceding *jowar* (Sorghum) crop had also been manured with 14 lbs. of nitrogen and 2½ tons of farmyard manure. Equivalent amounts of safflower cake (28 lbs. nitrogen) also gave a response of approximately 100 lbs. when applied singly or in combination with farmyard manure, only when the previous *jowar* was manured. Otherwise the cake was inffective on a basal dressing of farm yard manure.

At Arbhavi, phosphates depressed yield when applied over 28 lbs. of nitrogen with or without farmyard manure. Artificial nitrogen also appeared to have decreased yield except when applied with farmyard manure. It should be noted in this connection that rainfall at Arbhavi is lower than at Dharwar. The no-manure plots in trials at Arbhai are, however, characterized by high yields of 600 to 1000 lbs. per acre. The farm is commanded by a canal and though it is not clear from the reports, the experiments were probably irrigated. The results are, therefore, difficult to explain.

CENTRAL PROVINCES.

(TABLE II. APPENDIX B.)

सत्यमेव जयते

Berar Farms.

While the whole of the cotton growing area in this province is included in the black soil tract, Berar forms the heart of this tract and is the most important cotton producing region in the province.

Akola—This is the principal experimental farm in Berar and a large number of manurial trials have been carried out here.

Increased responses to increasing doses of nitrogenous fertilizers were obtained. For an application of 40 lbs. of nitrogen, which was the maximum quantity tried, there was an average increase of 191 lbs. in yield. Response to nitrogen was decreased when applied over a basal dressing of farmyard manure or cattle dung. There was no response to either phosphate or potash, and results obtained with mixtures of nitrogen and phosphate or nitrogen and potash are in agreement with this. The only exception is a trial conducted from 1909 to 1921 in which there was an increase of 116 to 173 lbs. in yield from an application of 20 and 40 lbs. of phosphate (P_2O_5). Other responses in this trial were also considerably higher than in later experiments. This is at least partly due to the cumulative action of feritlizers. The trial, however, consisted of a set of unreplicated plots and the results cannot be considered conclusive.

Groundnut cake gave steadily increasing yields with increased application, comparing favourably with those obtained from artificial nitrogen. As will be shown later, the results here and elsewhere demonstrate that this cake is a very promising source of nitrogen for manuring cotton. Responses to castor cake or to cattle dung were poorer and did not show any tendency to improve with higher rates of application.

A mixture of ammonium sulphate and cattle dung, to supply 20 lbs. of nitrogen each, gave a slightly lower increase in yield than 20 lbs. of nitrogen in the form of ammonium sulphate alone. Mixtures of ammonium sulphate and groundnut cake gave increasing and satisfactory responses. It is doubtful, however, if the mixture possesses any special advantage, since its performance is in accordance with the expectation from the results of the individual components. Addition of superphosphate to groundnut cake did not improve the result. A small addition of superphosphate to caster cake appears to have increased the yield in one trial but the effect diminished with higher doses of phosphate.

Experiments on the time of application of nitrogenous fertilizers show that application at sowing was better than six weeks later, but a divided application, half at sowing and half six weeks later, was probably equally satisfactory.

Buldana—Excepting one unreplicated trial in 1929, a basal dressing of farmyard manure was invariably used. Over this dressing, 20 lbs. of artificial nitrogen gave a moderate increase in yield. Phosphate and potash were not effective ; but an addition of 45 lbs. of phosphate (P_2O_5) to nitrogen appeared to have improved the response slightly.

Yeotmal—An average response of 100 lbs. of cotton to 20 lbs. of nitrogen as ammonium sulphate was obtained. There was a slightly lower response to an equivalent amount of groundnut cake. A basal dressing of dung enhanced the response to nitrogen, particularly in the form of groundnut cake. A mixture of the cake and ammonium sulphate gave results to be expected on the basis of the value of the individual components. Application of nitrogen appeared distinctly more effective six weeks later than at sowing time. In comparing the results at this station with those at Akola, it has to be remembered that the average rainfall at Yeotmal was 37·0 inches against 28·0 inches at Akola during the same period (1921—29). This difference can explain the beneficial effect of a basal dressing of dung and of the later application of nitrogen at Yeotmal.

Borgaon and Basim—Good responses to groundnut cake were observed at these stations. In the trials carried out for one season, there was a response of 115 lbs. to 19 lbs. of nitrogen as groundnut cake and a slightly lower increase from an application of a mixture of groundnut cake and ammonium sulphate supplying an equal quantity of nitrogen.

Other Central Provinces Farms.

Nagpur—Increasing responses to increased doses of nitrogen were observed ; but the responses were somewhat lower than at Akola. Addition of phosphate to nitrogen did not improve the results. Potash also was not effective. In fact, a mixture of phosphate and potash depressed yield. These two in combination with nitrogen showed an increased response only in an old unreplicated trial (1906—20) similar to that at Akola.

Application of nitrogen six weeks later appeared just slightly better than at sowing. It may be noted in this connection that rainfall at Nagpur also is higher than at Akola.

Three hundred and twenty pounds (26 lbs. nitrogen) groundnut cake was used in one trial and an increase of 143 lbs. was obtained in yield. No other data for trials with organic manures are available.

Khandwa—A basal dressing of farmyard manure was applied in almost all trials. On this dressing, there was a moderate response to nitrogen and none to phosphate or potash. There was an increasing response to larger applications of niciphos, but the phosphate component did not appear to be effective.

Powarkhera (*Hoshangabad*)—There was a fairly good response to 20 lbs. nitrogen per acre. An equivalent quantity of farmyard manure gave a lower increase which was doubled by doubling the dose of farmyard manure.

Chandkheri—The station is located on infertile lateritic soil in the eastern part of the province. There was no response either to artificial nitrogen or phosphate. Ten tons of cattle dung (40 lbs. nitrogen) increased yield by 120 lbs.

CENTRAL INDIA.

(TABLE III. APPENDIX B.)

Indore—Manurial trials were conducted at the Institute of Plant Industry and date from the year 1936. The trials were all properly designed and replicated and are specially interesting, because many of them were simultaneously laid out on land of distinctly different levels of fertility. In the Table, results are separately recorded for poor fields (with a yield of 274 lbs. per acre or less) and for the more fertile fields (giving 348 lbs. per acre or more). The average yields for the two types of fields were approximately 194 lbs. and 414 lbs. per acre. With very few exceptions, both artificial nitrogenous fertilizers and organic manures produced a good response on the more fertile fields and a very much smaller or no response on poor fields. This result is apparently contrary to the expectation that poorer fields should be more responsive to manuring than richer fields. From a careful examination of the results it appears, however, that the poor fields are characterized not so much by a deficiency of essential nutrients as by poor drainage and waterlogging which interfere with the growth of the cotton plant and its capacity to respond to manuring. The following comparisons illustrate this point :—

Response in lbs. per acre to 25 lbs. N (ammonium sulphate).

	1937.	1938.	1939.
Fertile fields	96 (5)	86 (6)	92 (3)
Poor fields	60 (2)	14 (6)	136 (1)
Rainfall (inches), June	8·3	14·0	1·9
July	14·8	17·3	8·8
Annual total	38·6	50·3	29·9

Figures in brackets are for the number of experiments over which the response is an average.

सत्यमेव जयते

It is clear that in poor fields the response was closely related to the total amount of rainfall and its distribution. The response in 1938 was least when conditions most favourable for waterlogging existed. It may be mentioned here that owing to a high proportion of clay in the black soil its drainage is rapidly impeded through frequent heavy showers. From a study of the rainfall data at Indore for the past 18 years it was observed that there is a close positive association between the amount of seasonal rainfall and the frequency of heavy showers. Another pertinent observation is that in the same set of rich and poor fields in which the average yield of cotton on rich land was 2·7 times as much as that on poor land, the yield of wheat, which is grown in the dry season following rains, was only 1·4 times as much as that on poor land. This observation supports the view that the poor yields of cotton—and its poor response to manure—are more due to its susceptibility to waterlogging than due to a deficiency of essential nutrients in the soil.

Turning to the effect of manures on the better fields, there was an increasing response to increased application of nitrogen. An average increase of 102 lbs. in yield was obtained for a dose of 50 lbs. of nitrogen in trials carried out in 1937 and 1938. In a trial carried out in 1939, the increase was as high as 192 lbs. for an application of 40 lbs. of nitrogen. Phosphate and potash showed no effect. Compost frequently gave a small but significant increase in yield for quantities supplying 18 to 50 lbs. of nitrogen per acre. Groundnut cake gave promising results. Other cakes were tried only in 1938, and among these linseed cake gave good increases in yield. *Til* (Sesamum) cake was not effective.

In two experiments, drilling the manure was compared with broadcasting, and in other three, different times of application of manure were tried. The results were not conclusive in either case ; but there is an indication that drilling might prove more efficient, and regarding the time of application, there is little possibility of gain by delaying the application of nitrogen, either in part or full, beyond the sowing time.

MADRAS PROVINCE.

(TABLE IV. APPENDIX B.)

The cotton area in this province may be broadly divided into three zones. In a belt of black cotton soil running along the southern border of Hyderabad State, mixtures of varying proportions of *G. arboreum* var. *neglectum* and of the more sympodial forms of *G. herbaceum* var. *frutescens* are grown under the commercial name Westerns and Northerns. In the eastern portion of this belt, only *G. arboreum* is grown and is commercially known as Coconadas. The experiment stations of Hagari, Bellari, Nandyal and Guntur are situated in this belt. Farther south, irrigated Cambodia (*G. hirsutum*) is grown on red soil in Coimbatore and Salem districts. There is a second black soil tract extending to the coast in the extreme south of the peninsula. The cotton grown is again a mixture of *G. arboreum* and *G. herbaceum* and is commercially known as Tinnevellies. The experiment station of Koilpatti serves this tract.

Hagari, Bellari, Nandyal and Guntur.

At Hagari and Nandyal there was no response to fertilizers. At Bellari, application of fertilizers caused a depression in yield. Rainfall at Bellari is also the lowest among the four stations. A comparison of responses to 45 lbs. of nitrogen and 20 lbs. of phosphate at Hagari, Nandyal and Guntur is interesting. During the years of the experiment, the rainfall at Hagari and Nandyal was 23 and 25 inches and the increases in yield 24 and 50 lbs. respectively. At Guntur the rainfall was 35 inches and the fertilizer increased yield by 97 lbs.

At Bellari, safflower cake also depressed yield. Cattle manure was not effective at Nandyal except with repeated application, but at Hagari even repeated application had no appreciable effect on yield.

On account of the low and precarious rainfall in this tract, further manurial trials on cotton do not appear worth while except in Guntur area.

Coimbatore.

Manurial trials at this station were carried out mostly on irrigated Cambodia.

No appreciable response to nitrogenous fertilizers was observed except when 60 lbs. of nitrogen was applied on a rather poor field newly brought under irrigation (field 3). The effect of phosphate appeared to be similarly dependent on the fertility of the soil. 60 and 80 lbs. of phosphate increased yield by 148 and 72 lbs. in the old permanent manurial trial and in field 3 respectively, both of which are characterized by much lower yields than the new permanent trial and field 5, which did not respond to phosphate. Potash had no effect on yield under either condition.

In the only experiments carried out on unirrigated *Karunganni* cotton (*G. arboreum* var. *neglectum* forma *indica*), 45 lbs. of nitrogen and 20 lbs. of phosphate had no effect on yield when applied over 4½ tons of cattle manure, either on red or black soil.

There was a striking response to continuous application of cattle manure (56 lbs. nitrogen) as seen from the results of both permanent manurial series. Residual effects of cattle manure also appear to persist over long periods. In another experiment, 7½ tons of cattle manure (84 lbs. N) produced an average increase of 210 lbs. in yield and response to manure increased with more frequent irrigation, as is to be expected.

Koilpatti.

The results of manurial trials at this station differ from those at the other stations in the province, in that a consistent response was observed to both organic and inorganic manures. The average annual rainfall of 29 inches is moderate but proximity to sea would lessen losses of moisture from the soil through evaporation.

There was an increasing response to increased application of nitrogen. Yield was increased by 142 lbs. by applying 45 lbs. of nitrogen in one dose before sowing. Early application appeared better than a split application in two or three doses. There was a response of 182 lbs. to 57 lbs. of phosphate also ; but in conjunction with *neem* (margosa) cake phosphate was not effective. The response to potash cannot be separately evaluated ; but increases ranging from 104 lbs. to 842 lbs. were obtained from mixed fertilizers containing varying amounts of nitrogen, phosphate and potash. Addition of the last two manurial elements appears to have enhanced the response to nitrogen. Phosphate was equally effective whether through superphosphate or basic slag. It should be noted that the increase in yield of 170 lbs. per acre resulting from an application of 45 lbs. of nitrogen and 20 lbs. of phosphate was the highest in comparison with the magnitude of responses from this fertilizer at other stations in the province.

One thousand pounds of *neem* cake (55 lbs. nitrogen) gave an increase of 332 and 236 lbs. in yield in the absence and presence of 300 lbs. of superphosphate (57 lbs. P_2O_5) respectively. Mixtures of groundnut cake or groundnut cake and ammonium sulphate with superphosphate, supplying 20 to 40 lbs. of nitrogen and 20 lbs. of phosphate increased yield by 59 to 192 lbs. An increase of 123 lbs. can be ascribed to 250 lbs. of groundnut cake (20 lbs. nitrogen) over a dressing of 112 lbs. of ammonium sulphate and an equal amount of superphosphate. There were no trials in which the effect of cattle manure could be studied.

In future manurial trials in this tract, it is desirable to asses the real value of phosphate and potash, in view of the encouraging responses obtained from fertilizers containing these components.

सत्यमेव जयते

UNITED PROVINCES.

(TABLE V. APPENDIX B.)

Cotton is cultivated in the western and south-western parts of the province and the variety is an inferior ***desi*** (***G. arboreum*** var. ***neglectum*** forma ***bengalensis***) commercially known as bengals. Excepting two or three experiments in past years at Cawnpore, manurial trials in this province date only from 1938 and were conducted at Raya in Muttra district.

Doses of nitrogen up to 45 lbs. per acre were tried and there was an increasing response to increased application. For 45 lbs. of nitrogen there was an increase of 236 lbs. in the yield of *desi* cotton in a trial in 1939. In this trial both *desi* and American varieties were grown and it was found that the American responded much less to nitrogen than *desi* . There was no response to nitrogen at Cawnpore. Both at Cawnpore and Raya, the application of phosphate with or without nitrogen did not improve yield but at Raya 52 lbs. of potash (K_2O) in potassium nitrate applied at the rate of 20 lbs. nitrogen per acre gave an average increase of 199 lbs. in yield over 20 lbs. of nitrogen alone, in a set of trials conducted for three years. This is the only striking response to potash observed during the present investigation.

The time of application of fertilizers, either at sowing or 1½ month later, made no difference.

Three hundred pounds of castor cake (20 lbs. nitrogen) or 4 tons of compost did not affect yield at Raya ; but both at Raya and Cawnpore, farmyard manure increased yield.

PUNJAB.

(TABLE VI. APPENDIX B.)

The canal colony in the central part of the province forms the largest and most important area of cultivation of American (*G. hirsutum*) cotton in India. The crop is irrigated. *Desi* (*G. arboreum* var. *neglectum* forma *bengalensis*) is scattered over all cotton growing areas in the province, and a very large proportion of the *desi* cotton is also irrigated. In the eastern and south-eastern districts only *desi* cotton is grown.

Irrigated American cotton.

Lyallpur.

Responses to nitrogen were extremely heterogeneous, both as regards seasons and different fields in the same season. Considerable increases in yield, 250 lbs. or more, were sometimes obtained for relatively small doses of nitrogen, *i.e.*, up to 30 lbs. per acre, but there was frequently very little increase in yield or even a significant decrease in a few cases. This heterogeneity is reflected in the responses not showing any increasing trend with larger doses of nitrogen. In the light of recent work in connection with the failure of the cotton crop in Punjab (Dastur, 1941) the variation must be ascribed to the presence of salinity in the soil. Manurial treatments, mostly single doses of artificial nitrogen, formed part of the trials carried out by Dastur at Lyallpur and other centres, and classifying the responses to nitrogen in these trials according to the nature of the soil, the following results are obtained.

Nature of Soil.	Increase in yield, lbs. per acre, per lb. of nitrogen.	
Light sandy soil (free from salinity)	8·84	(9)
,, ,, ,, saline subsoil	7·28	(7)
Sandy loam, saline subsoil	2·13	(5)
,, ,, highly saline subsoil	1·05	(4)

The numbers in brackets refer to the number of trials from which the averages are calculated. Response to nitrogen is reduced as salinity increases, particularly in loamy soil.

The low average responses obtained at Lyallpur thus appear to be the result of a considerable extent of salinity present in the experimental fields. In some trials carried out in the tenants' area, responses were considerably greater. At Khanewal (Multan district) too, larger increases in yield than at Lyallpur were obtained. According to Dastur's findings, there is only a moderate degree of salinity in the subsoil at Khanewal. Cotton on such soil is expected to show a better response to nitrogen than on saline soil. The difference is illustrated by the following results which are averages of comparable data from a number of trials.

Dose of nitrogen, lbs. per acre.	Increase in yield, lbs. per acre.		
	Lyallpur farm.	Tenants' area.	Khanewal.
16	55±18	174±38	183±31
24	44±18	188±38	

The variation in response to the same quantity of nitrogen in the three groups of trials is striking.

Phosphate was without any effect while potash definitely depressed yield when applied either by itself or in combination with phosphate. The probable explanation is that potash being easily soluble would increase salinity in the soil.

Application of nitrogen towards the end of August, during flowering, was found to be most beneficial.

Five tons of farmyard manure (56 lbs. nitrogen) increased yield by 118 lbs. but an equivalent amount of dung used in one trial caused a decrease, though this was not significant. Five hundred and sixty pounds of *Toria* (Mustard) cake gave very promising results considering its nitrogen content of only 22 lbs. *Mahua* (Bassia Latifolia) cake was also tried ; but this cake is not useful as a source of nitrogen owing to the presence of saponin, which retards nitrification.

Trials were carried out by the Imperial Chemical Industrices in 1936 and 1937 at Kote Branford Estate (Lyallpur), Brucepur (Lyallpur) and Pirawala (Multan). Good responses to nitrogen were obtained in all trials ; but the increases were larger at Kote Brandford and Pirawala than at Brucepur. Application of nitrogen during intensive flowering, in the first fortnight of August, gave the best results.

Okara.

Experiments at this station were also conducted by the Imperial Chemical Industries. Responses to nitrogen were satisfactory though fluctuating. Phosphate and potash did not increase yield by themselves, but results of trials with niciphos indicate that the response to nitrogen was enhanced by the addition of phosphate. An average increase of 340 lbs. was obtained from an application of 60 lbs. of nitrogen and 60 lbs. of phosphate (P_2O_5) in trials extending over four years.

Irrigated desi cotton.

Hansi, Sirsa.

These stations are situated in the *desi* tract in the south-eastern part of the province.

Consistent responses to nitrogen, increasing with increased rates of application, were obtained at Hansi. In one trial there was an average increase of 611 lbs. in yield from 80 lbs. of nitrogen supplied through 400 lbs. of ammonium sulphate or 520 lbs. of sodium nitrate. This is one of the largest responses observed in the course of the present analysis. For equal nitrogen content, calcium cynamide was less effective than sodium nitrate or ammonium sulphate. At Sirsa, too, considerable responses to nitrogen were obtained in a trial carried out in 1928. There was no response either to phosphate or potash.

Five to seven tons of farmyard manure (56 to 80 lbs. nitrogen) produced appreciable increases in yield, but the average response for equivalent quantities of castor cake (55 to 80 lbs. nitrogen) was much less. Addition of bonemeal to farmyard manure does not appear to have enhanced the effect while its addition to castor cake showed a tendency to depress yield.

In the trial at Sirsa a mixture of farmyard manure with ammonium sulphate or with sodium nitrate on an approximately half and half basis gave results which were only as good as or less than increases obtained with half the quantity of nitrogen applied through sodium nitrate or ammonium sulphate alone. Supplementing farmyard manure with superphosphate or potash sulphate was also ineffective.

SIND.

(TABLE VII. APPENDIX B.)

The cotton tract in this province is similar to the canal colony in Punjab in soil and climate. Cotton is grown on irrigation and though the indigenous variety is inferior *bengals* (*G. arboreum* var. *neglctum* forma *bengalensis*) it is being rapidly replaced by American (*G. hirsutum*) strains, particularly in the southern districts on the left bank of the Indus.

Only results of manurial trials carried out by the Imperial Chemical Industries on American cotton from 1934 to 1937 are available for this province.

Sakrand.

Heavy doses of compost at sowing (118 lbs. nitrogen) or half this quantity of compost at sowing followed by 22 to 44 lbs. of nitrogen as ammonium sulphate applied 8 to 14 weeks after sowing produced very high responses.

On the land of the British Cotton Growers' Association at Berani (Nawabshah) also, cotton responded to nitrogen. The addition of phosphate was not effective.

Mirpurkhas.

There was an average response of 168 lbs. to 30 lbs. of nitrogen in two seasons' trials. Application at intensive flowering was better than earlier applications. Nitrogen applied with seed showed a tendency to depress yield in a trial in 1937. Addition of phosphate to nitrogen had a similar effect; but in the 1937 trial, a dose of 16 lbs. of phosphate (P_2O_5) with seed gave an increase of 522 lbs. This is a phenomenal result and cannot be considered conclusive without confirmation.

At Bodar (Thar Parkar, Sind Land Development Co.) increasing responses to nitrogen up to a maximum of 361 lbs. for 60 lbs. of nitrogen were obtained in 1937. In another trial in 1936, a response of 414 lbs. to 33 lbs. of nitrogen applied at intensive flowering was observed against only 75 lbs. when the same quantity of nitrogen was given at first watering. Addition of phosphate to nitrogen appeared to decrease yield.

In two trials at Denisar Estate (Thar Parkar) also, there was a good response to 30 lbs. of nitrogen, but an early application gave better results. When applied early, the addition of phosphate seemed to improve yield.

The results of the trials at different centres give an indication of some heterogeneity of response to artificial nitrogen similar to that observed in Punjab and the same factor of soil salinity is probably operating here; but the number of experiments is too few for this point to be examined closely.

सत्यमेव जयते

(*b*) CONCLUSIONS.

Considering the vastness of area and the heterogeneity of conditions—in soil, climate, agricultural practices, varieties—under which cotton is grown, any general conclusions on manuring embracing the whole range are hardly to be expected. It is, however, encouraging to find that definite information on a number of points is available from the foregoing summary of results. On a few points, the conclusions are common to the whole area of cotton cultivation while on others they are applicable to large sections of the area.

Of the three chief fertilizer elements, nitrogen, phosphate and potash, application of nitrogen alone is found essential for increasing yield. The other two, phosphate and potash, did not affect yield favourably. Potash proved to be without any value at all centres (excepting the solitary result at Raya in United Provinces). Phosphate also showed no beneficial effect over any large tract and is clearly of no primary importance. In a recent review of the fertilizer trials carried out on different crops in Britain and the northern European countries, Crowther and Yates (1941) observe that it is the acid soils that stand in particular need of phosphate fertilizers. If this rule is applicable here, the general lack of response to phosphate can be easily understood. The black cotton soil is characterized by an abundant reserve of lime and is distinctly alkaline in reaction. Irrigated soil in Punjab and Sind also tends to be alkaline due to accumulation of salts through irrigation. Thus, conditions favourable for a general phosphate deficiency do not ordinarily exist; but there are apparently patches of soil in different tracts where cotton responds to phosphate either singly or in combination with the nitrogen, as results at Dabhoi in Gujerat, on red soil of rather low fertility at Coimbatore and at Okara in Punjab indicate. It is desirable to mark out, through further trials, areas where the nitrogenous manuring of cotton may be profitably augmented by the addition of phosphate. A general soil survey of the cotton tracts would help to determine the location of these trials.

Both irrigated and rain-fed cotton respond to nitrogen, irrigated cotton on the whole showing larger responses, which is to be expected. The difference is clearly seen by comparing responses shown in tables VI and VII in Appendix B for Punjab and Sind with those in the other provinces. The fact that cotton is irrigated in Punjab and Sind is obviously the most important single factor responsible for the larger yields and large responses to nitrogen obtained in the two provinces. To the universal increase in yield brought about by nitrogen, two exceptions were observed. These are :

(1) In the irrigated tract, presence of soil salinity prevents the crop from responding to the fertilizer. This explains the heterogeneous nature of results obtained at Lyallpur and elsewhere including an adverse effect on the crop in some trials. Dastur's trials in Punjab have demonstrated the close connection between the degree of soil salinity and the magnitude of the response of cotton to application of nitrogen.

(2) In rain-fed areas, manuring is not effective where rainfall is low. Under the more extreme conditions it may even depress yield. This is illustrated by the results obtained at Dhulia in Western Khandesh district in Bombay and at the stations situated in the black soil belt in Madras on the southern border of Hyderabad State. With such a low and precarious rainfall, manurial trials do not hold any promise of usefulness. The real problem in these areas is one of making sufficient moisture available to the crop and not of manuring.

On the black soil, response to nitrogen is also seriously reduced on poorly drained land subject to waterlogging, as the results at Indore show. Optimum moisture availability thus appears to be an essential condition for securing the largest increases in yield from nitrogen, an excess of water as well as its deficit, whether physical or physiological, being detrimental to an efficient utilization of the manure. It is also clear that under rain-fed conditions improvement of drainage and prevention of waterlogging are necessary before the full benefit of manuring poor land may be realized.

A comparison between artifical fertilizers and other nitrogenous manures available from local sources is of particular interest. Artificials were mostly used for supplying nitrogen to the crop in the trials in Punjab and Sind ; but *Toria* (mustard) cake which was tried in a few experiments in Punjab has given encouraging results and should be given further trial. For rain-fed cotton on black soil, groundnut cake appears to be an excellent source of nitrogen and there is evidence to indicate that its efficiency may be even higher than of ammonium sulphate. Under the uncontrolled moisture conditions prevalent in rain-fed areas a part of the nitrogen from ammonium sulphate is liable to be lost without being utilized by the cotton plant, whereas nitrogen from the cake becomes more gradually and steadily available. Larger quantities of free ammonia were actually found in ammonium sulphate plots than in groundnut cake plots in a recent cotton manurial trial at Indore (Sreenivasan, unpublished). Since groundnut cultivation in black soil is extensive and is yet increasing, the problem of profitable utilization of the cake as a cotton manure deserves a careful study, both in its agricultural and commercial aspects. *Neem* (margosa) cake has also given very promising results at Koilpatti in the extreme south of the peninsula. Castor cake was not generally as good as these cakes and appears more variable in its effect.

For equal amounts of nitrogen, farmyard manure or compost usually gave a much smaller increase in yield than either artificials or oil cakes. The nitrogen content of farmyard manure is low, being only 0·5 per cent compared to 8 per cent of groundnut cake and 20 per cent of ammonium sulphate, and its release in a form suitable for use by the crop is dependent upon the stage of decomposition of the manure and the amount of moisture present in the soil.

Under certain conditions, farmyard manure might even utilize the nitrogen and moisture in the soil for further decomposition thereby depleting the supply of these elements to the crop. With adequate rainfall or with irrigation this manure is more consistently useful. The relative efficiency of nitrogen from different sources is discussed further in the next chapter.

The view that artificials should preferably be applied in mixture with organic manures has received considerable emphasis in the past. Evidence of this is to be found in the Tables in Appendix B, where nitrogenous treatments consisting of an artificial fertilizer on a basal dressing of farmyard manure or dung or green manure are of common occurrence. The other combination frequently employed is the mixture of oil cakes and artificials. The results obtained with the mixture of groundnut cake and ammonium sulphate at different stations in the black soil tract (Jalgaon, Akola, Yeotmal) lead to the conclusion that under rain-fed conditions the mixture does not confer any special benefit on crop yield beyond that to be expected from the effect of the individual components. On the other hand, inorganic nitrogen in combination with farmyard manure, dung or green manure has often produced a smaller increase in yield than when applied alone. This is illustrated by results obtained at Jalgaon and Akola. Under irrigated conditions, results at Sirsa (Punjab) are similar. At Sakrand, ammonium sulphate over a dressing of compost gave high responses ; but it is not possible to compare these with the increases that might be obtained from artificial nitrogen alone. From the experimental data available, it is thus clear that a combination of artificials and organic manures is not as useful as is generally supposed. With farmyard manure particularly, it would be a sounder policy to reserve the limited supplies that are available for manuring cereals grown in rotation with cotton, especially in rain fed areas with a moderate rainfall, rather than applying it in combination with artificials or oilcakes to cotton.

On the optimum time for applying nitrogen, some definite indications are available from the present analysis. For irrigated American cotton in Punjab and Sind, application during intensive flowering is shown to give the best results. This period corresponds with the latter half of August in Punjab and a week or ten days earlier in Sind. With *desi* cotton (C. 520 strain) at Raya in United Provinces, time of application either at sowing or 1½ month later, made no difference. For rain-fed arboreum cotton on black soil an early application appears to be the best, except possibly where rainfall is higher (Yeotmal, Nagpur) and an application six weeks after sowing is slightly better. The arboreum cotton grown on black soil is a sympodial early maturing type. The herbaceum cotton of Gujerat is more monopodial, produces more prolific vegetative growth and matures later. Results at Surat show that application of nitrogen to this cotton is more profitable when done six weeks after sowing than at sowing. These conclusions are in agreement with Crowther's (1938) recommendations regarding the optimum time for fertilizer application to Indian cottons. The optimum dates, wherever they are later, may require modification when oilcakes are used as a source of nitrogen, since these nitrify more slowly than artificials. In future trials, time of application will have to be one of the factors to be taken into account in comparing oilcakes with artificials.

The most efficient method of applying the manure is an important aspect of manuring, particularly in rainfed areas where the manure broadcast on the surface is liable to be washed away by heavy showers. The alternative method of drilling it close to the seed furrow is likely to conserve it better and make it easily accessible to the young seedling. Experimental data on methods of applying manures are scanty ; but at Indore indications were obtained that drilling the manure might prove better than broadcasting it. Applying the manure in a very close proximity of the seed, either by drilling it along with the seed or by coating the seed with it, appears to result in loss of germination and consequent loss in yield. The evidence on this point is provided by trials on irrigated cotton at Mirpurkhas and on unirrigated cotton at different centres in Central Provinces and at Indore. With regard to the coating of seed with the fertilizer in particular, a very considerable increase in yield was observed in a preliminary trial at Khandwa (Kalamkar, 1942) but in later trials it was found that the exceedingly good bearing of individual plants was not sufficient to make up for the loss of stand, through defective germination, which was rather severe. Drilling the manure in a separate furrow would appear safer and needs to be tried.

The question of vital practical importance with regard to manuring is whether and under what conditions it will pay. While it is clear from the summary of results discussed here that nitrogen does increase cotton yield, it cannot provide an answer to this question without a further statistical examination of the data, with the additional factor of the price of manure and of cotton taken into account. The results of past trials, though admittedly inadequate for drawing conclusions of serious practical value on the various aspects of the economics of manuring, were analysed from this angle and are described in the next chapter with a view to illustrate the procedures that might be employed in such a study and to indicate what particular deficiencies are responsible for the limited usefulness of the present data.

REFERENCES.

1. Crowther, E. M. and Yates F.. . (1941) *Emp. J. Exp. Agric. 9*, 77—97.
2. Crowther, F. ... ... (1938) *Ind. J. Agric. Sci. 8*, 617—628.
3. **Dastur, R. H.** ... ... (1941) *I. C. C. C. 2nd Conf. of Sci. Res. Workers in India*, Cotton Agric, Paper No. 9.
4. **Kalamkar, R. J.** ... ... (1942) *Curr. Sci, 11*, 190.

सत्यमेव जयते

CHAPTER III.

NITROGENOUS MANURING OF COTTON.

(*a*) ECONOMICS OF MANURING.

While nitrogen has been generally shown to increase the yield of cotton, this increase will be profitable to the grower only when its money value is sufficient to leave a balance after paying the cost of manure applied. Recommendations on manuring that will guarantee profits to an individual grower cannot obviously be made without trial on his own land; but a practicable alternative is to carry out a number of suitable trials on representative fields, and from their results estimate expected profits and define as precisely as possible the conditions under which these profits may be realized. The trials whose data are available were mostly confined to experimental stations and cannot be considered representative. The results obtained are, however, interesting, and are presented here with the primary object of providing guidance in planning future trials.

Consideration of profits involves the ruling prices of manure and of cotton. Both factors are variable, and it is therefore necessary to take their normal range into account. It was decided to use for this purpose the prices prevailing during the most recent normal period of ten years, 1928 to 1937. Available information from different experiment stations on the cost of various manures used in the cotton trials and prices realised for cotton during this period is recorded in Tables I and II, Appendix C. A comparison of the prices of ammonium sulphate and of groundnut cake on the basis of their nitrogen content is of interest. Parallel prices for both are available for the seven year period, 1930—36, at Akola, Koilpatti and Coimbatore. Average costs per pound of nitrogen are shown below.

Average cost in rupees per lb. nitrogen, 1930—36.

	Ammonium sulphate.	Groundnut cake.
Akola	.288	·272
Koilpatti	·328	·537
Coimbatore	·275	·356

Groundnut cake was 5·6 per cent cheaper than ammonium sulphate at Akola; but at Coimbatore it was 29·5 per cent and at Koilpatti 63·7 per cent costlier.

The difference in the relative prices of the two manures at Akola on one hand and at Koilpatti and Coimbatore on the other is due to the fact that groundnut cultivation is extensive in Berar and plenty of cake is produced locally, whereas the other two stations represent areas in which the cultivation of groundnut is limited and the cake has to be imported. Even so, during the latter part of the ten year period the price of the cake was recording a steady decline both at Koilpatti and Coimbatore, and it is reasonable to assume that the disparity between the prices of the cake and ammonium sulphate will disappear when normal conditions are re-established.

Farmyard manure occupies a different position. Ordinarily, a farmer has his own supplies of this manure and its cost is then nil; but if the manure has to be purchased, data in Table II show that the range of prices per unit of nitrogen partly overlaps those for ammonium sulphate or groundnut cake. From this Table the following ranges may be adopted for different manures in studying profits.

Price range, rupees per lb. nitrogen.

Ammonium sulphate	·25 —·50
Groundnut cake	·20 —·40 —·70
Farmyard manure	·15 —·40

The more extreme value for groundnut cake is the one reached at Koilpatti in 1930-31 ; but the prices at Akola may be taken to be more representative, and the normal range for the cake may be regarded as ·20—·40 rupee per pound of nitrogen.

For inferior quality cotton like roseum, bengals or northerns, the range of price may be taken as ·06 to ·14 rupee per pound of *kapas* (seed cotton), while for superior cottons like Verum, Cambodia or Punjab Americans a range from ·09 to ·19 is more appropriate.

In evaluating profits it is first necessary to formulate the relationship between the amount of manure and the corresponding increase in yield, by trying a wide range of manurial dressings. For a generalization of conclusions, estimates of profit should be based on a knowledge of this relationship rather than on experimental responses obtained for particular quantities of manure. Past trials, however, do not provide the data needed for an adequate determination of the exact nature of this relationship. In a large number of trials only a single level of nitrogen was tried and the maximum quantity applied did not exceed 50 lbs. of nitrogen per acre. Larger doses were tried only in a few trials with farmyard manure on rain-fed cotton, and in three or four recent trials with artificial nitrogen on irrigated cotton. Under these circumstances, the nature of the relationship between amount of nitrogen and increase in yield has to be assumed on *a priori* basis. The following three alternative forms of the response curve deserve examination.

(1) A straight line, *i.e.*, response proportional to the quantity of nitrogen. In fact, this is the only form of relationship available if data from all trials, including those with only a single dressing of nitrogen, are to be utilized. In view of the low value of the maximum amount of nitrogen applied in the trials, a straight line may provide a good approximation to more complex relationships within the range of quantities tried.

(2) The assumption of linearity cannot, however, hold over any considerable range of nitrogen doses, *i.e.*, the response will not be proportional to the quantity of nitrogen for larger dressings. The straight line is thus of little value in representing the general nature of the response curve. To account for the fall in response with larger quantities of nitrogen various curves can be thought of. Data from trials where at least two doses of nitrogen were tried are needed for their determination, and all trials with only a single dose have to be discarded. The simplest of such curves is a second degree parabola of the form $Y = A + Bx + Cx^2$, where Y is the response expected from a dose of x lbs. of nitrogen. This form of the response curve was adopted by Sukhatme (1941) in studying the economics of manuring of paddy. The second degree parabola, however, implies too rapid a fall in response after the maximum response is attained. This defect can be remedied by cubic or other curves of a higher degree which will represent the real situation more closely. To fit such curves results from at least three dressings of nitrogen are needed ; but hardly any such trials can be found among past data.

(3) The third alternative is a curve representing some empirical rule governing response to manure. The Mitscherlich equation provides such a curve. The equation is

$$Y = Y_0 + d\,(1 - 10^{-kx})$$

where Y is the yield in the presence of a quantity x of a fertilizer, Y_0 the no-manure yield and d the limiting response. The constant k measures the curvature of the response curve—the greater its value the less will the crop respond to increasing levels of the fertilizer. The Mitscherlich Law states that the response to each unit dressing of a fertilizer bears a constant ratio to the additional response to the next unit. Crowther and Yates (1941) have employed the Mitscherlich curve as a basis for recommending allocation of optimum dressings of fertilizers to different crops in Great Britain. The curve rises asymptotically to the limiting response and thus precludes the possibility of the response to a unit dressing of the fertilizer at a higher level being actually less than that to a unit at a lower level. This might be so when the manure is acting under optimum conditions as in pot culture, but under the field conditions with which we are dealing here, there are obvious limiting factors, such as moisture or soil salinity, which can diminish response to larger dressings to such an extent that the response curve may register a downward slope after reaching the maximum. Even with the moderate dressings of nitrogen that were tried in the cotton trials, evidence of the operation of these factors was available and has been discussed in the last chapter.

Due to these limitations of the different response curves, conclusions regarding profits or optimum dressings derived from them by extrapolation beyond the range of dressings actually tried must be taken as tentative and as mainly indicating the necessity of applying larger quantities of manure experimentally in order to determine the precise shape of the response curve.

With a linear relationship between response and quantity of nitrogen, the equation of the response curve is simply $Y=bx$, where Y is the response expected for x lbs. of nitrogen and b the regression coefficient. If p represents the price per pound of seed cotton, the money value of the response is pbx and deducting the cost of nitrogen, say q rupees per pound of nitrogen, the expression for profit from the application of x lbs. of nitrogen becomes

$$pbx - qx \text{ or } px\left(b - \frac{q}{p}\right).$$

This simply means that manuring will be profitable when the ratio $\frac{q}{p} = \frac{\text{price per lb. of nitrogen}}{\text{price per lb. of seed cotton}}$ is less than b. If this ratio is larger there will be loss; but whether profit or loss, it will increase steadily in proportion to the dressing of nitrogen given, and there cannot be an optimum dressing.

This consequence of assuming the response curve to be a straight line does not appear sound in practice and only shows that the assumption cannot be valid indefinitely.

For the second degree parabola, the response to a dressing of x lbs. of nitrogen is given by the expression $Y=Bx+Cx^2$ where the coefficients B and C are related to the coefficients B' and C' of the orthogonal polynomial of the second degree in x by the equations

$$B=B'-2C'\bar{x} \text{ and } C=C'$$

The expression for profit is,

$$pBx+pCx^2-qx$$

from which the expected profit from the application of a given quantity of nitrogen may be calculated. By maximising this expression, the optimum dressing of nitrogen, that is one that will yield maximum profits, can be obtained. This quantity (X) is

$$X=\frac{1}{2C}\left(\frac{q}{p}-B\right)$$

and its numerical value may be found from a knowledge of the numerical values of the constants of the response curve.

According to the Mitscherlich curve profit is represented by the expression

$$pd\,(1-10^{-kx})-qx$$

The optimum dressing obtained by maximising this expression is

$$X=\frac{1}{k}\left(\log\frac{dk}{\cdot 4343}-\log\frac{q}{p}\right).$$

These three types of response curve were fitted to average responses to different dressings of nitrogen. The responses were grouped according to the source of nitrogen: (1) from artificials, (2) from groundnut cake and (3) from farmyard manure or compost. Trials on rain-fed cotton in black soil and on irrigated cotton in the alluvial soil of Punjab and Sind are considered separately. The results are briefly described below.

The fitting of the second degree parabola was usually carried out by means of orthogonal polynomials, and the linear regression coefficients of the straight line and of the parabola are identical as shown in the Tables below; but where the doses of manure were at unequal intervals the second degree curve was fitted to yield by the method of partial regression, and this was then expressed as an orthogonal polynomial with the help of expected yields at equal intervals from the partial regression curve. The response curve with which we are really concerned was not affected by this procedure ; but the linear regression corresponding to this polynomial differs from the true linear regression and explains the discrepancy observed between the two coefficients in one or two places.

Rain-fed cotton.

The largest number of trials with artificial nitrogen, mostly as ammonium sulphate, were available at Indore. Of these, 22 included two dressings of nitrogen and the remaining three, one dressing. The maximum quantity of nitrogen supplied was 50 lbs. per acre. The curves fitted to the average responses from 22 trials are shown in Fig. 2a and the increases in yield to be expected for different doses of nitrogen on the basis of these curves are given below.

Responses to artificial nitrogen at Indore.

(lbs. seed cotton per acre)

Dose of N.	Linear.	Polynomial.	Mitscherlich.
10	24	29	27
20	49	56	52
30	74	80	74
40	98	102	94
50	122	122	112
Coefficients	b = 2·45	B′ = + 2·4842 C′ = — ·0114	k = + ·0047

It is clear from the graph and from the Table above that responses are practically linear within the range of quantities of nitrogen tried. In comparable trials at Akola and Nagpur responses were slightly smaller and the response curves approximated even more closely to a straight line. At Jalgaon, in six trials with a single dressing, the linear regression coefficient b was 6·1 which is considerably higher than at other centres ; but the maximum quantity of nitrogen tried was only 20 lbs. per acre. We may, on the available data, take the Indore results as being typical for rain-fed cotton on black soil.

It has been shown above that the price ratio $\frac{q}{p}$ plays an important part in determining profits and optimum doses. According to the straight line, application of ammonium sulphate will be profitable only when this ratio is less than 2·5. From the prices of ammonium sulphate and of seed-cotton, the ratio $\frac{q}{p}$ may be taken to vary between 1·5 and 6·0. Optimum doses of nitrogen calculated from the polynomial and Mitscherlich curves over this range of the ratio are :

Optimum dose of artificial nitrogen.

(lbs. per acre)

$\frac{q}{p}$	Polynomial.	Mitscherlich.
1·5	141	61
2·5	97	14
4·5	10	...
6·0	...	...

Owing to the disparity between the optima indicated by the two curves and the fact that they fall mostly outside the range of quantities tried, not much value can be attached to these figures.

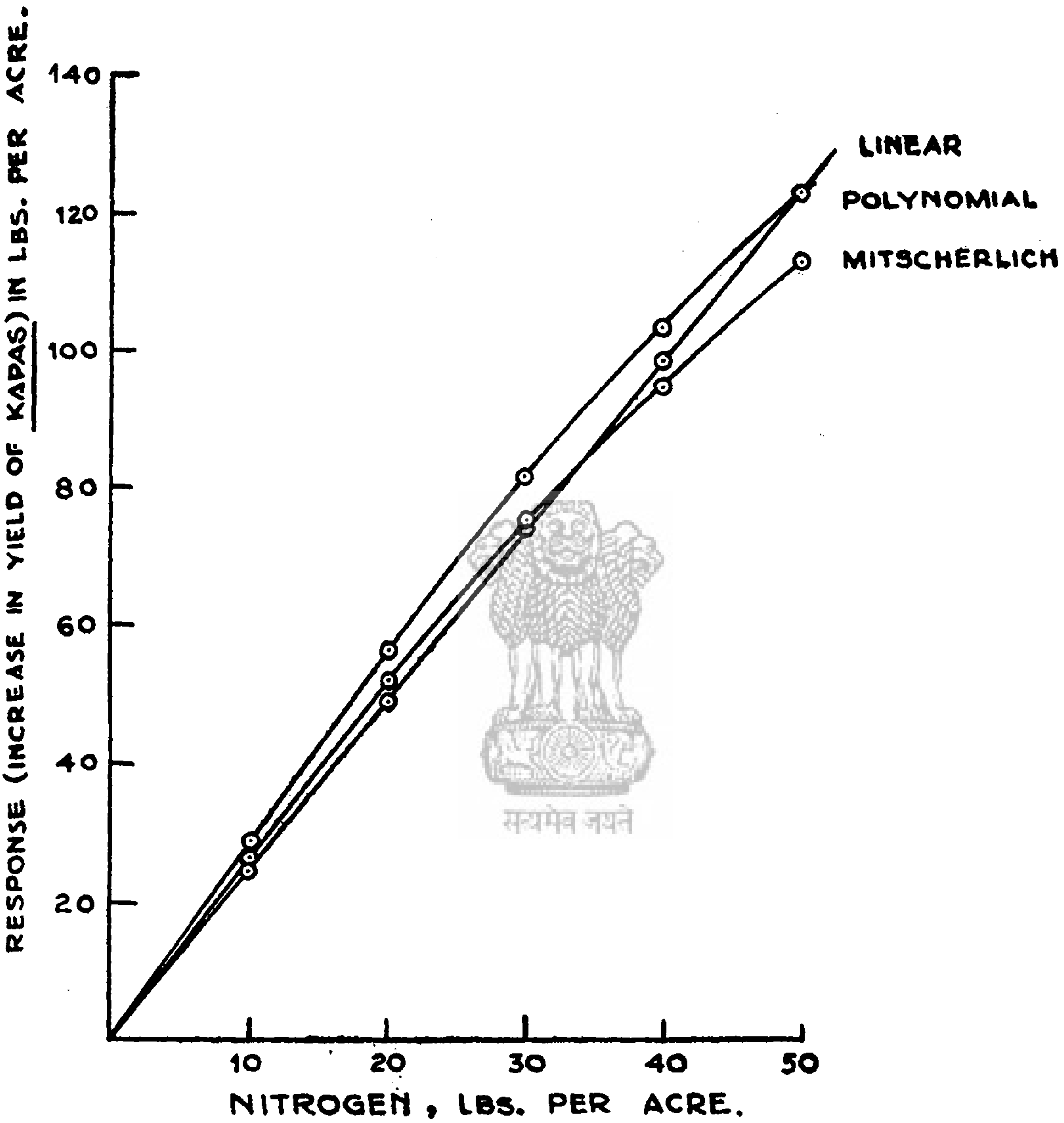


FIG. 2 a. RESPONSE TO AMMONIUM SULPHATE AT INDORE.

Trials with groundnut cake were mainly carried out at Akola. There are eight comparable trials with two or more doses and the largest quantity tried was equivalent to 40 lbs. of nitrogen per acre. Responses calculated from different response curves are given below and the curves are shown in Fig. 2 b.

Response to groundnut cake at Akola.

Dose of N.	Linear.	Polynomial.	Mitscherlich.
10	39	50	48
20	77	91	81
30	116	123	103
40	154	147	118
50	193	162	128
	Coefficients b = + 3·86		B′ = + 3·2869 k = + ·0171 C′ = − ·0433

For calculating profits the ratio $\frac{q}{p}$ for groundnut cake may be taken to range from 1·0 to 5·0. With the straight line which still provides a tolerable approximation to the other curves, the value of the ratio marking the dividing line between profit and loss is 3·9 approximately. From the other two curves, the optimum dressings in terms of nitrogen in lbs. per acre are

Optimum dose of nitrogen.

$\frac{q}{p}$	Polynomial	Mitscherlich.
1·0	51	45
2·0	39	27
3·0	28	17
4·0	16	10
5·0	5	4

सत्यमेव जयते

There is a fair agreement between the values from the two curves and these indicate an optimum dressing up to 40 lbs. of nitrogen per acre. In only two other trials at Indore, three doses of groundnut cake up to a maximum of 50 lbs. of nitrogen per acre were tried. The polynomial and Mitscherlich curves fitted to these trials show less curvature than at Akola and give larger optimum doses for the lower values of the ratio $\frac{q}{p}$. It should be noted that the average linear regression coefficient for all 17 trials at Akola is 3·3, while that for eight trials at Indore and Nagpur is 3·4.

Both at Indore and Nagpur the rate of increase in yield per lb. of nitrogen is larger for groundnut cake than for ammonium sulphate. At Akola, the average linear regression coefficient for ammonium sulphate is 4·4 over seven trials; but the majority of these had lower dressings of nitrogen than trials with the cake. Ammonium sulphate was applied in two doses, 20 and 40 lbs. of nitrogen per acre, only in one trial at Akola, and the linear regression coefficient in this trial was 2·4. With the more uniform response of cotton to groundnut cake than to ammonium sulphate and with the price more favourable to the cake, there is little doubt that the cake provides a more generally profitable manure for cotton on black soil than ammonium sulphate; but for a critical comparison of the efficiency of the cake and ammonium sulphate more strictly comparable and more abundant data are needed than are available in the past trials.

Eleven trials carried out at Indore provide data on the response to farmyard manure. In eight of these, two dressings equivalent to 25 and 50 lbs. of nitrogen per acre were applied. Responses based on the three response curves are shown below and the response curves are drawn in Fig. 2c.

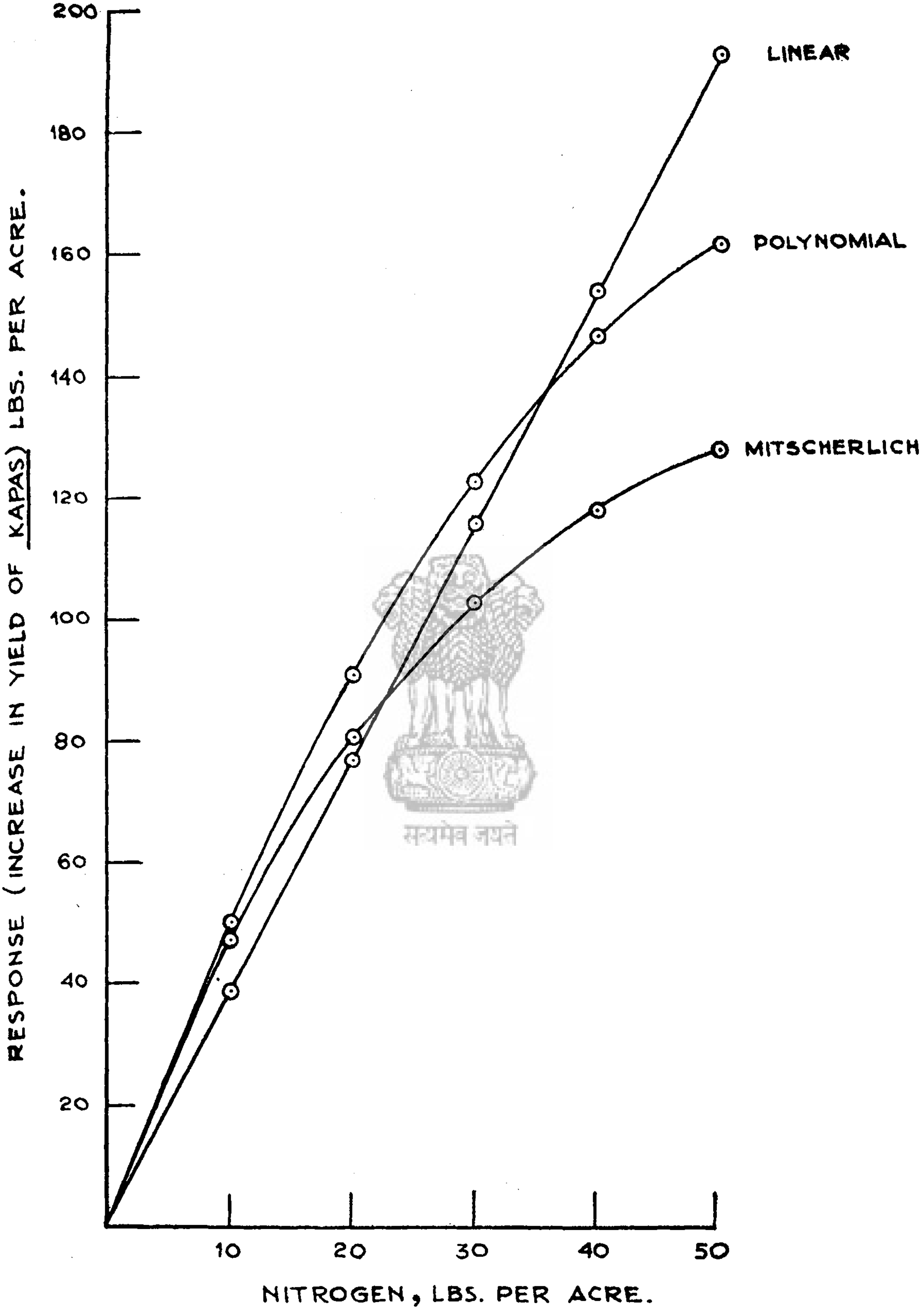


FIG. 2 b. RESPONSE TO GROUNDNUT CAKE AT AKOLA.

सत्यमेव जयते

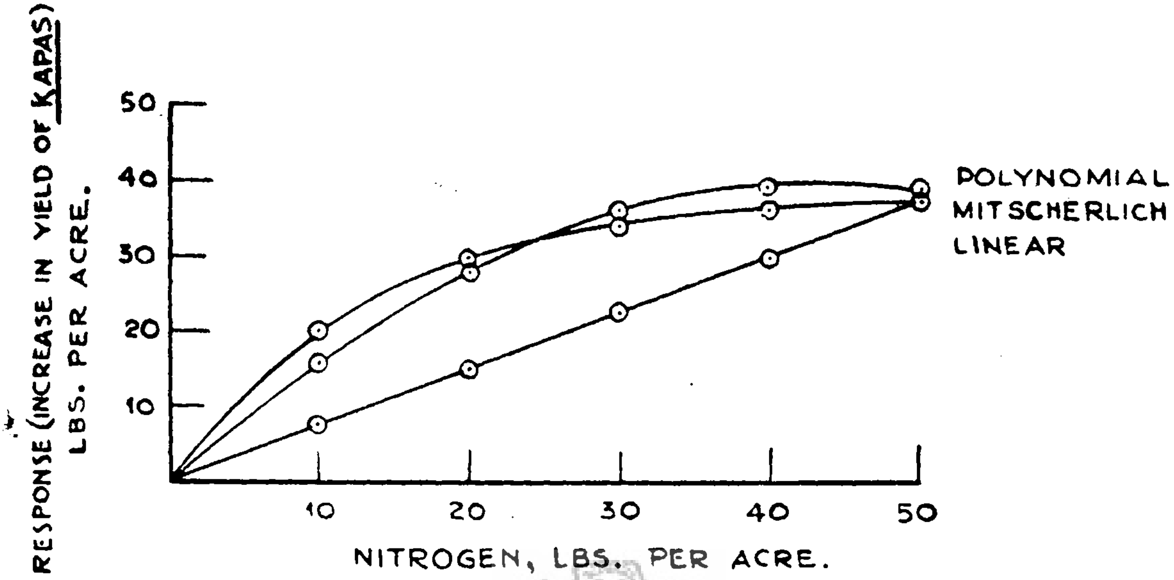


FIG. 2 c. RESPONSE TO FARMYARD MANURE AT INDORE.

सत्यमेव जयते

Response to farmyard manure at Indore.

Dose of N.	Linear.	Polynomial.	Mitscherlich.
10	8	16	20
20	15	28	29
30	23	36	34
40	30	39	36
50	38	38	37

Coefficients b = + ·76 B′ = + ·7575 k = + ·0828
C′ = — ·0217

Increase in yield per pound of nitrogen is considerably less for farmyard manure than for ammonium sulphate or groundnut cake. The curvature of the polynomial and Mitscherlich curves is also greater and the responses calculated from these two curves agree closely. For farmyard manure, the price ratio $\frac{q}{p}$, appears to vary in the range 0·8 to 5·0. According to the straight line, the application of farmyard manure will be profitable only when the ratio is less than ·76 which is outside the range but the other two response curves differ appreciably from the straight line, and the optimum doses from these curves are

Optimum dose of nitrogen.

$\frac{q}{p}$.	Polynomial.	Mitscherlich.
0·8	24	17
1·0	19	14
2·0	...	5

Provided the price per lb. of nitrogen in farmyard manure does not exceed that per lb. of seed cotton, a small quantity of nitrogen, 15 to 20 lbs. per acre, seems to be the optimum dressing.

Trials with farmyard manure at other centres included only a single dose. The average regression coefficient for 20 such trials at Akola, Jalgaon, Dhulia, Dharwar and Nandyal was 1·4. For Akola and Jalgaon only, where conditions are more favourable than at other centres, the coefficient was 1·7. In either case the value of the coefficient is larger than at Indore. At Indore, farm compost made by the Indore process was mostly used in the trials, whereas at other stations, it was the usual farmyard manure. Even under the most favourable conditions the increase in yield per lb. of nitrogen from farmyard manure is clearly much less than from groundnut cake or ammonium sulphate.

We may conclude from the present analysis that groundnut cake is probably the most suitable manure for cotton on black soil. Its optimum dose may be tentatively given as being in the neighbourhood of 40 lbs. of nitrogen per acre which is equivalent to 500 lbs. of the cake. Farmyard manure does increase yield ; but its application will not ordinarily be profitable when the manure has to be purchased. To maintain fertility of land, periodic addition of farmyard manure is, however, considered necessary, and the proper stage in the crop rotation for its application needs careful study.

Irrigated cotton.

Data for artificial nitrogen only are available for irrigated cotton in Punjab and Sind.

Of the 17 trials on American cotton at Lyallpur, only six included two dressings of nitrogen with a maximum of 34 lbs. per acre. The responses calculated from the three response curves fitted to these latter trials are given below and the curves are shown in Fig. 3 a.

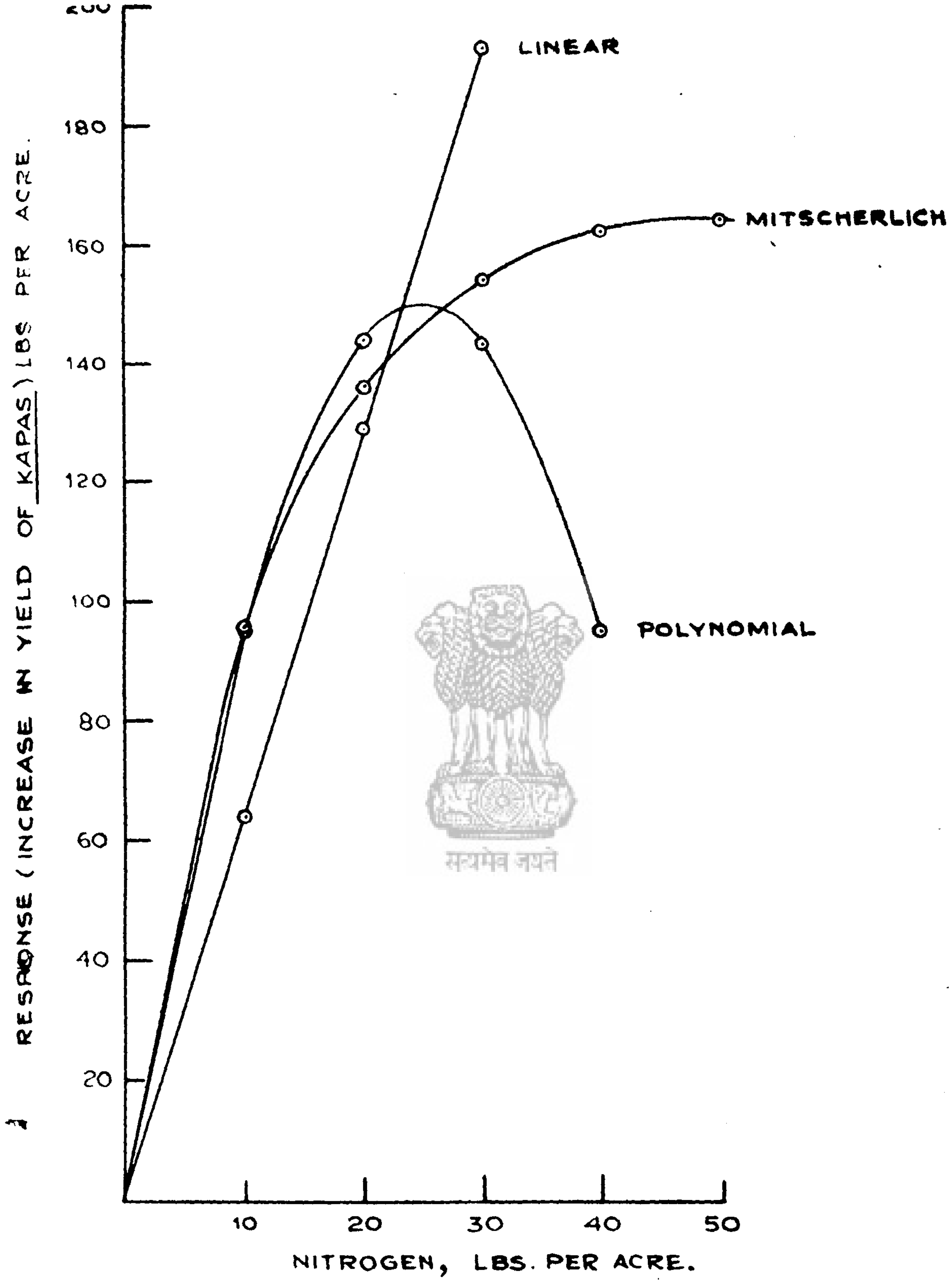


FIG. 3 a. RESPONSE TO AMMONIUM SULPHATE AT LYALLPUR.

Responses to artificial nitrogen, Lyallpur.

Dose of N.	Linear.	Polynomial.	Mitscherlich.
10	64	96	95
20	129	144	186
30	193	148	154
40	298	95	161
50	322	...	164
	Coefficients b = + 6·44		B′ = + 4·7849 k = + 0·0867 C′ = — ·2857

Even with the comparatively small quantities of nitrogen tried, both the polynomial and Mitscherlich curves show a marked curvature, reflecting the effect of increase in soil salinity resulting from the addition of soluble salts. Of the 17 trials, the linear regression coefficients have a negative sign in five. Among the six trials with two doses, there was one with a negative linear coefficient. The optimum quantities calculated from the two response curves are only between 20 and 40 lbs. of nitrogen per acre; but even this conclusion is of little practical value. Among the trials at Lyallpur are included two trials on tenants' land outside the research farm. It will be recalled that the responses to nitrogen were very considerbly better in these two trials than at the farm and the present results are strongly influenced by these. If the two trials are omitted, the average linear regression coefficient of the remaining 15 trials is reduced to 1·1, the second degree parabola fitted to the four trials now available has a minimum instead of a maximum, and k, the constant of the Mitscherlich curve, becomes negative.

A negative value of k signifies that the response to each successive unit of nitrogen is larger than the response to the previous unit which is contrary to the usual expectation. An attempt to fit a Mitscherlich curve to the trials of Risalewala failed altogether. Mean yields of 11 trials at Risalewala with 0, 16 and 24 lbs. of nitrogen per acre were

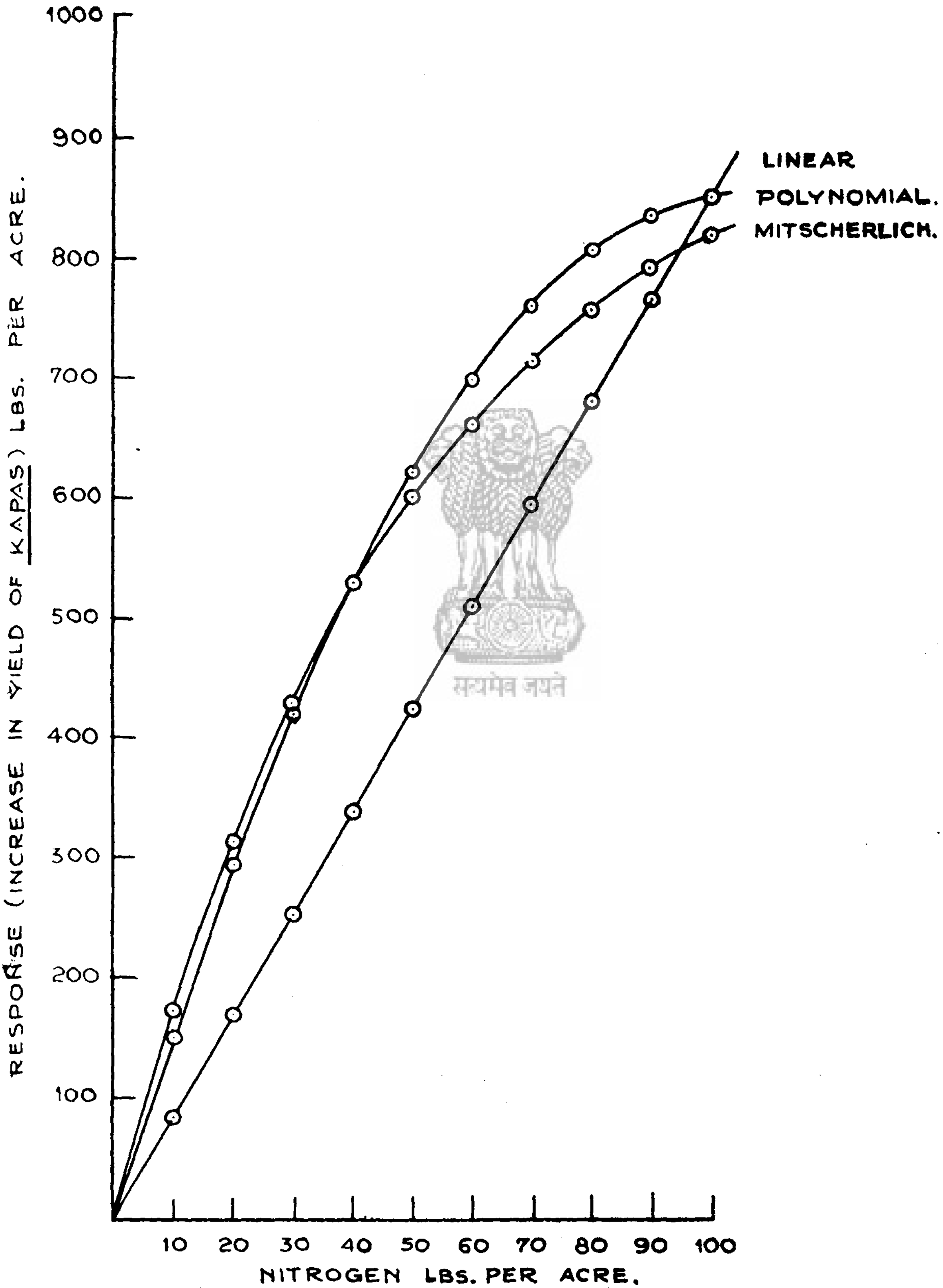
	Nitrogen lbs. per acre.		
	0	16	24
Yield of seed cotton lbs. per acre ...	558	609	589

The response to the second dressing was negative and a numerical value for k could not be calculated. The Mitscherlich equation is apparently inapplicable to these results.

Evidence of the overwhelming effect of soil salinity in diminishing response to nitrogen to the extent of even depressing yield is now clear.

On the other hand, large responses to manuring appear possible under irrigation, where this factor does not interfere. The trials on tenants' land at Lyallpur, Dastur's recent trials on land free from salinity and the trials by the Imperial Chemical Industries at Khanewal, Okara, Kote Branford, Brucepur and Pirawala are all characterized by high responses to nitrogen. It may be recalled that in Dastur's trials on light sandy soil free from salinity the average linear regression coefficient is 8·8. Unfortunately, only two of these trials included more than one dose of nitrogen, actually 50 and 100 lbs. per acre; but their results are given below as indicating the possibilities of manuring cotton under suitable conditions. The curves fitted to the two trials are shown in Fig. 3 b. Responses based on these curves are

Dose of N.	Linear.	Polynomial.	Mitscherlich.
20	170	296	814
40	341	529	528
60	509	699	662
80	679	806	755
100	849	849	817
Coefficients b = + 8·49		B′ = + 8·4900 C′ = — ·0790	k = + ·0088



RESPONSE (INCREASE IN YIELD OF KAPAS) LBS. PER ACRE.
1000
900
800
700
600
500
400
300
200
100
10
20
30
40
50
60
70
80
90
100
NITROGEN LBS. PER ACRE.
LINEAR
POLYNOMIAL.
MITSCHERLICH.

सत्यमेव जयते

These responses are larger than any obtained from trials in the rain-fed tract. Results from the polynomial and Mitscherlich curves agree closely. Optimum dressings corresponding to these two curves are given below.

	Nitrogen lbs. per acre.	
$\frac{q}{p}$	Polynomial.	Mitscherlich.
1	97	146
2	91	111
3	85	91
4	78	77
5	72	66
6	66	57

Large dressings of nitrogen, up to 100 lbs. per acre or more, appear profitable over a wide range of prices and indicate that there is scope for manuring cotton on a really heavy scale. Manuring of cotton at this rate is not uncommon in Egypt (Crowther, 1939).

Of the nine trials with artificial nitrogen whose data are available for Sind, only two, one at Berani and the other at Bodar, included a range of dressings up to 75 lbs. nitrogen per acre. A dressing of about 50 lbs. per acre appears to give maximum yield in these trials. A downward trend in the response curve is observed beyond 60 lbs. Responses in other trials however, indicate that in Sind as in Punjab large quantities of nitrogen may be applied to cotton profitably, and further work directed towards determining optimum dressings and optimum conditions for manuring is necessary.

(*b*) OPTIMUM CONDITIONS FOR MANURING

Conclusions derived from the average results obtained from the trials in a tract are not necessarily applicable to an individual holding since its conditions may not be quite similar to the average conditions in the tract. These conclusions only show how the growers would fare as a community, if a particular recommendation on manuring were commonly adopted in the tract. Failure to appreciate this interpretation of the results often causes individual growers, who experience a different type of response to manuring on their own fields, to discredit average values. The response of cotton to farmyard manure may be cited as an example. The foregoing results have clearly shown that under rain-fed conditions it is much less efficient than other manures like groundnut cake or ammonium sulphate and that its application is not generally profitable if the manure has to be paid for. In special circumstances, however, as when the crop is irrigated or the rainfall is sufficient, the soil has adequate moisture retentivity and the manure well-rotted, the increase in yield may be profitable. On the other hand, if the moisture is deficient in the soil or the manure is not sufficiently decomposed, it may involve the grower in a considerable loss. More specific recommendations are needed to meet situations like these, and for this purpose it is necessary to define the optimum conditions for manuring as precisely as possible.

Some of the factors which affect the efficiency of manuring were referred to in the course of the discussion of experimental results in the previous chapter. It was shown, for example, that excessive moisture or water-logging reduces the response of cotton to a given quantity of nitrogen, while a deficient moisture supply may even depress yield. Poor drainage in the black soil on which rain-fed cotton is grown or an undue accumulation of salts in the lighter alluvial soils on which irrigated cotton is grown, adversely affect its response to manuring. Good drainage of the soil and a fair amount of well distributed rainfall in rain-fed areas, and freedom from any appreciable degree of soil salinity in the irrigated tract may thus be included among the optimum conditions for manuring cotton. In order to obtain more critical evidence on these points, the experimental data available were subjected to a statistical analysis. The results are briefly described here. The analysis consisted of calculating suitable regressions of response to nitrogen on (1) fertility and (2) on the seasonal rainfall.

The rate of increase in yield per pound of nitrogen, that is the linear regression coefficient of the response curve, was used as the variate representing response in the individual trials. The difficulty arising out of the quantity of nitrogen applied differing from trial to trial was thus overcome. If suitable data were available, response calculated to a standard dressing, say 25 lbs. nitrogen per acre, from the appropriate response curve would be a preferable measure of response to use. In the present material, however, a large number of trials included only a single dressing and to utilise these results linear regression alone can be fitted. Moreover, it has been shown in the previous section that the straight line generally provides a tolerable approximation to other response curves within the range of dressings employed.

Fertility is difficult to define in terms of the chemical, physical or microbiological properties of the soil, since too many known and unknown factors are probably involved; but yield which represents the integrated result of all these may be taken as a single measure of fertility for our present purpose. The yield used was that of the control or no-manure plots. Yates (1935) has observed in this connection that estimate of regression of response on this yield is liable to be biased and that it is better to take mean yield of the whole trial as an index of fertility to avoid this bias; but when, as in the present case, the mean yield of the trial is influenced by wide variation in the treatments employed in the different trials, the no-manure yield would provide a more comparable measure of fertility than mean yield.

The true regression of response on no-manure yield is so related to the apparent regression based on experimental yields that except when the latter has a negative value less than unity, it underestimates the true value. The magnitude of bias depends on the ratio of experimental errors of yield to the real variation between experiments. The numerical values of the regression coefficients shown later in this section are mostly positive and the true regression would consequently be numerically larger. The difference will not be serious when, as would be expected, the experimental errors are small compared to real variation between trials, though this point needs verification on actual data.

Figures for rainfall consisted of the annual totals for the particular localities and years in which the trials were carried out. No attempt was made to take the distribution of the rainfall into account. It should be noted that centres with deficient rainfall where manuring was found to have affected the crop adversely were omitted from this analysis.

सत्यमेव जयते

Rain-fed cotton.

Twenty-five trials with dressings of ammonium sulphate were carried out at Indore during three years. To eliminate seasonal variation in studying the regression of response (response being represented by the linear regression coefficients in individual trials) on fertility, sums of squares and products within years alone were employed. Pooled over three years the analysis of variance of response is as follows;

Analysis of variance of response to ammonium sulphate.

Due to	d. f.	m. s.
Linear regression on fertility ...	1	15·10
Residual	21	3·78
Total within years ...	22	4·25

The regression which is positive ($b = + \cdot 0064$) is thus very nearly significant on the 5 per cent level and shows that as fertility increases response per unit of nitrogen applied as ammonium sulphate also increases. Consideration of the results for each year separately helps to show to what extent this relationship is affected by seasonal conditions.

The yearly analyses of variance are :—

Year	1937-38	1938-39	1939-40
Total rainfall (inches)	39	50	30

Analyses of variance

due to	d. f.	m. s.	d. f.	m. s.	d. f.	m. s.
Regression	1	0·24	1	24·28	1	1·34
Residual	5	5·89	10	1·66	4	5·33
Regression coefficient	·0022		·0096		—·0049	

The seasonal influence is clearly brought out here. It is only in a season of heavy rainfall that the positive association between response to nitrogen and fertility is definitely established. In discussing Indore trials in the previous chapter, it was stated that the lower response to manure on less fertile soil was not to be ascribed to any lack of essential nutrients but to water-logging resulting from poorer drainage from such soil. The present analysis has demonstrated the correctness of this conclusion.

Results with groundnut cake at Akola are similar though not equally conclusive. In two years, 1930-31 and 1931-32, there were six trials annually and the rainfall was 26" and 45" respectively. The regression coefficients of response to nitrogen on fertility were ·0016 and ·0078. Both coefficients are positive and again indicate a closer association in a year with a larger rainfall, though neither coefficient is statistically significant.

There were four trials with farmyard manure at Indore in 1937-38 and six in 1938-39. It is interesting to note that only in the second year, when the rainfall was 50", the regression coefficient was positive and the mean square for regression nearly three times the residual mean square, though not significant on the number of degrees of freedom available.

Thus, both for artificial and organic manures the available evidence points to a positive relationship between soil fertility and response per unit of nitrogen, particularly in seasons with heavy rainfall.

To study the effect of rainfall on response to nitrogen, observations are too few to be analysed separately for individual stations. A simple regression of response per unit of nitrogen on the seasonal rainfall was, therefore, calculated by pooling over different stations (Indore, Akola, Nagpur, Jalgaon, Koilpatti) the sums of squares and products between years. These, it will be remembered, were not taken into account in calculating the regression of response on fertility. For ammonium sulphate the regression was negative (b = —·096) and significant on the 5 per cent level. This means that the rate of increase in yield per unit of nitrogen is lowered as the seasonal rainfall increases. It should be noted, however, that rainfall was found to show a similar negative relationship with fertility. The regression coefficient of no-manure yield on rainfall is—13·2 and it is significant on 1 per cent level. Thus for an increase of one inch in the seasonal rainfall the yield per acre is reduced by 13·2 pounds of *kapas*. The question, therefore, arises as to what extent rainfall exercises a direct effect on response of cotton to manure, apart from that operating through its association with fertility.

To answer this question a joint regression of response on fertility and rainfall was calculated from the sum of squares and products between years, and from the sum of squares representing the joint regression with 2 degrees of freedom, that due to the simple regression of response on fertility was removed. The balance represents the effect of rainfall on response to nitrogen over and above its effect associated with fertility. The analysis of variance for the regression is shown below.

Analysis of variance (regression of response to nitrogen on rainfall and fertility).

Due to	d. f.	s. s.	m. s.	
Partial regression on fertility and rainfall ...	2	43·94		
Linear regression on fertility	1	38·64	38·64	Significant on 5 per cent level.
Balance representing regression on rainfall independent of its association with fertility ...	1	5·30	5·30	
Residual	14	100·31	7·16	

It is clear that the negative association between response to manure and the seasonal rainfall is due to the latter's interaction with the yielding capacity of the soil. Rainfall does not appear to exercise any additional direct influence on the increase in yield from manuring.

For groundnut cake (Akola, Indore) similar inter-relationships between response to manure, fertility and rainfall were observed; but the analysis was based on only 4 degrees of freedom and none of these was significant. The simple regression coefficients of fertility on rainfall and of response on rainfall were—18·4 and—·044 respectively.

Results with farmyard manure (Akola, Indore, Jalgaon) are similar in that the simple regressions of response on rainfall and of fertility on rainfall are negative, the coefficients being —·011 and —9·21 respectively; but there is a significant negative association between rainfall and response to manure after the effect of the interaction between rainfall and fertility is eliminated. When, however, results for Jalgaon, where the rainfall was less in the particular seasons than at the other two centres and unlike these centres the association between rainfall and fertility was positive, are omitted, the recalculated regressions are of the same character as for the other two manures, though all non-significant.

We may, therefore, conclude that higher rainfall reduces the response to nitrogen, whether organic or inorganic, but it acts mostly through its influence on soil fertility.

Irrigated cotton.

Responses to artificial nitrogen and no-manure were examined by the same procedure for several stations in the Punjab. From pooled analyses of variance and co-variance of the linear regression coefficients for response and no-manure yields, regressions were spearately calculated from between years and within years. These showed a positive association between response to nitrogen and fertility. Between years the regression coefficient was highly significant while within years it fell short of significance on the 5 per cent level. These results were mainly influenced by Lyallpur and Okara.

सत्यमेव जयते

The analyses of variance for regression at these stations are shown below.

Analysis of variance (regression of response on fertility).

		Lyallpur. d. f.	Lyallpur. m.s.	Okara. d.f.	Okara. m. s.
Between years ...	Regression on fertility	1	384·9*	1	6·5
	Residual	7	15·4	2	15·2
Within years	Regression on fertility	1	94·4	1	34·5*
	Residual	7	45·6	6	2·5
Regression Coefficient	Between years		·0130		—·0048
	Within years		·0059		·0135

The significant results within years are parallel to those obtained on rain-fed cotton and lead to the same conclusion, *viz.*, as fertility of the soil increases the rate of increase in yield per unit of nitrogen is also enhanced. The significantly positive results between seasons point to an interaction between fertility and some seasonal factor in affecting response to nitrogen. Rainfall as a factor in this connection is of no consequence in the irrigated tract. The average annual rainfall at Lyallpur does not exceed 15 inches. Temperature may play an important part. Milne (1922) had suggested high temperatures in September and October as a possible cause for the failure of cotton crop in the Punjab. This was confirmed by Dastur (1941) who showed that a continued spell of hot weather during fruiting resulted in bad opening of bolls and poor yield. He has further shown that the interaction between temperature and soil salinity is responsible for a wide variation in yield on the same land in different years. Thus, a moderate degree of salinity coupled with favourable weather may not affect yield adversely to any appreciable extent, but with unfavourable weather the same degree of salinity is liable to cause a partial failure of the crop. An extension of the present analysis by taking into account an appropriate measure of weather temperatures during fruiting is thus likely to give interesting and valuable results; but on the evidence available here we may safely conclude that response to nitrogen is directly affected by fertility, and indirectly by some seasonal factor like temperature operating through its effect on fertility.

The present examination of optimum conditions for manuring has thus given the remarkable conclusion, common to both irrigated and rain-fed cotton, that *soil and climatic factors which increase yield also increase the response of cotton to nitrogen.* The low responses observed on poor fields at Indore thus appear to have a wide significance and we are now led to look upon the most important function of manuring being not as a corrective for overcoming defective soil conditions, but as a means of maximum exploitation of the optimum conditions under which cotton should be grown. It is of immediate practical value to study relative responses to manure on inherently poor fields where no explanation for low yields can be found in terms of the physical environment as also on different broad classes of soil within a tract. It is, however, clear that where poor drainage and water-logging or an excessive degree of soil salinity are the causes of low yields, their removal is necessary before satisfactory returns from manuring cotton on such fields can be realized.

The statistical analysis of available data has thus led to some interesting and useful conclusions on the economics and optimum conditions of manuring, but their tentative character, because of the extreme inadequecy of the results, has been made clear both in this chapter and elsewhere. The need of more extensive series of planned trials to set them on a sound footing may be emphasized once more. The subject of planning future manurial trials is discussed in the next chapter.

---

* Significant on 1 per cent level.

References.

1. Crowther, F. ... ... (1939) *Agric. and Livestock in India*, *9*, 401.

2. Crowther, E. M., and Yates, F. ... (1941) *Emp. J. Exp. Agric.*, *9*, 77.

3. Dastur, R. H. ... . (1941) *I.C.C.C. 2nd Conf. of Sci. Res. Workers in India*, Cotton Agric. Paper No. *9*.

4. Milne, D. ... ... (1922) Report Dept. Agric., Punjab, Part II. Annual Experiment Record.

5. Sukhatme, P. V. ... ... (1941) *Ind. J. Agri. Sci.*, *11*, 325.

6. Yates, F. ... ... (1935) *Suppl. J. Roy. Stat. Soc.*, *2*, 154.

सत्यमेव जयते

CHAPTER IV.

PLANNING OF FUTURE EXPERIMENTAL WORK.

From the foregoing analysis of results of past trials, it will be seen that considerable information has been secured on certain broad facts relating to the manuring of cotton. While it provides a very valuable basis for planning future trials, we are admittedly far from the position of being able to make with any confidence explicit recommendations on manuring to cotton growers in the different tracts. It has been established, for instance, that only nitrogenous manures are needed for increasing yield; but our knowledge regarding optimum quantities for application or of the conditions under which the most satisfactory responses may be realized is still meagre. The obvious explanation for this situation is that past trials were not directed towards elucidation of the various aspects of manuring treated as a single comprehensive problem; but consisted of the examination of isolated and mutually unconnected items on a background of pre-existing notions. It should also be added that the experimenters were handicapped for want of adequate knowledge of the fundamental principles of field experiments, which is a development of a very recent date.

To ensure rapid progess in the systematic accumulation of essential knowledge regarding the manuring of cotton and to avoid wasteful effort, it is most desirable that future manurial trials should form part of a well considered and co-ordinated plan. Owing to the vastness and heterogeneity of cotton areas in India, a large number of trials will naturally have to be carried out, and these can be utilized to the fullest extent only if they are projected to provide answers to a questionnaire clearly and precisely drawn up. A further advantage of such a programme will be that results of trials in neighbouring provinces and States, when viewed together, will bring out many additional facts and lead to more sound conclusions than would be possible otherwise. For example, important cotton areas in Bombay, Madras, Hyderabad State, Madhya Pradesh, and Madhya Bharat are situated in the black soil tract. A co-ordinated plan for manurial trials in all these areas will add immensely to the value of their results. The same is true of Sind and Punjab taken together. The Indian Central Cotton Committee forms the most suitable medium for this co-ordination and it is encouraging to note that a beginning has already been made towards this objective. It is proposed to discuss here an outline of the future programme of manurial trials on the basis of the information gathered in the present investigation. For preparing detailed designs for individual experiments it is necessary to take into account local agronomic conditions.

Manurial trials, like all other agricultural research, should be of two kinds : (1) detailed experimentation at research stations and Government Farms to discover new facts and (2) extensive trials with a very simple lay-out to verify and demonstrate on cultivators' land and under their conditions the results obtained at research centres.

There are several factors connected with manuring which were either not properly investigated previously or on which past trials have not given conclusive evidence. Among these, optimum dressings of manure and improvement in the efficiency of the utilization of the manure by the crop are important. According to principles of modern field experiments, as many relevant factors as possible should be studied in a single experiment, because by so doing new sets of conditions resulting from the simultaneous variation of the levels of different factors are introduced into the experiment. These additional conditions cannot be studied if each factor were to be tried singly in separate trials. The lay-outs are consequently elaborate and involve a large number of plots, and such experiments can be undertaken only at research stations or farms where adequate facilities are available. Crowther's work on cotton manuring in Egypt (Crowther and others, 1935, 1936) is an excellent illustration of the power of this type of experiment in providing practical and scientific information of great value. Some of his trials included as many as 72 different treatment combinations and over 200 plots, and occupied ten acres of land. The more important factors which need examination in connection with cotton manuring in India are briefly listed below.

Quantity of nitrogen. It is of primary importance to study the true nature of the relationship between the quantity of nitrogen applied and the increase in yield obtained in the different tracts. A knowledge of this relationship (the response curve) is the basis for determining the optimum dose both agriculturally and economically. Quantities of nitrogen covering a wide range must be tried for this purpose. For rain-fed cotton, doses suggested are, 0, 20, 40 and 60 lbs. of nitrogen per acre, while for irrigated cotton which can utilize larger amounts, dressings of 0, 30, 60 and 90 lbs. are more appropriate. Application of 60 and 90 lbs. of nitrogen might be considered uneconomical; but it is obvious that in order to determine the optimum, quantities beyond the possible optimum must be used. In fact, when results of trials with the proposed dressings are available it might be found advisable to try still larger quantities. The failure to appreciate the necessity of experimenting with large applications of nitrogen was responsible for the extreme inadequacy of data from past trials to supply information on the economics of manuring.

Alternative sources of nitrogen. Under rain-fed conditions, groundnut cake has proved the most promising source of nitrogen compared to ammonium sulphate or farmyard manure; but its superiority was inferred mostly through indirect evidence. A more conclusive test of the efficiency of cake is necessary by including it with equivalent amounts of ammonium sulphate, in the same trials. At Koilpatti in the south, *neem* (margosa) cake had given very encouraging results in some old trials. Confirmation of these results would be desirble by comparing different quantities of nitrogen in the form of *neem* and groundnut cake in the Tinnevelly area. Though farmyard manure has been shown to be of limited utility in its fertilizer value for the cotton crop in rain-fed areas, most of the cotton growers are familiar with this manure only, and trials may be laid out to demonstrate the greater value of groundnut cake.

Nitrogen from organic sources was tried in very few experiments in the irrigated tract; but results obtained with *Toria* (mustard) cake at Lyallpur and with farmyard manure at other centres are promising, and indicate the need of further trial with these manures. Groundnut cake, which proved to be an efficient source of nitrogen under dry conditions, has not been tried in irrigated areas. A comparison between ammonium sulphate, groundnut cake, other locally available cakes and farmyard manure on the basis of equal amounts of nitrogen will provide much needed information on the possibility of using nitrogen from indigenous and may be cheaper sources for manuring irrigated cotton.

Time of applying manures. The stage at which manure is applied to a crop makes a significant difference in the resulting increase in yield. Information on the optimum time of manuring cotton is fairly definite and further trials are not necessary on this point, except in the irrigated tract where a comparison between organic and inorganic nitrogen is suggested. Since the nitrification of oil cakes and of farmyard manure is slower than that of ammonium sulphate, applying organic manure at an earlier stage than at flowering, which is the optimum stage for adding artificials, would appear desirable. To verify this, early, divided and late application of manure should be compared in experiments in which nitrogen from organic and inorganic sources is included.

Method of applying manures. This factor is of particular importance in the rain-fed tract, where the manure applied on the surface by broadcasting is liable to be washed away by heavy showers, and even when it is not, it might not become quickly available to the young seedling with a deepening root system. Kalamkar's experiment (1942) with cotton seed coated with ammonium sulphate gave very striking increases in yield; but there is some experimental evidence now that this method of application is not safe due to the possibility of germination of the coated seed being severely damaged. An alternative method, to place the manure very near to the seed without allowing the seed to come into actual contact with it, is to drill the manure in a separate furrow close to the seed furrow. Lewis (1941) has shown that different methods of placement of fertilizers made considerable differences in the yield of root crops.

Application of phosphate. Past results have been generally conclusive in showing that application of phosphate alone or with nitrogen is not effective in increasing cotton yield. Experiments at a few stations, however, have given positive results. For example, phosphate appeared to be a useful manurial constituent at Koilpatti in Madras, and in the Imperial

Chemical Industries experiments at Okara in Punjab and at Mirpurkhas and Denisar Estate in Sind. To verify these results and to mark out, if possible, areas where phosphatic manuring would be advantageous, about two levels of phosphate, say 20 and 40 lbs. of P_2O_5 per acre, might be included along with dressings of nitrogen in future trials. In view of the past results, one or two seasons' work should ordinarily suffice to show whether the experiment need be continued further at any of the stations.

The general lack of response to phosphate observed in the past trials may be partly due to the low level of nitrogen at which phosphate was tried, but if nitrogeneous manuring is to become a widespread practice and is to maintain its effectiveness, care will have to be taken of the availability of phosphate to the crop, since unless the available amount of phosphate from the soil is replenished, this might tend to become a limiting factor in the course of time. Secondly as Stewart (1947) has emphasized in his report, the general immobility of phosphate in the soil and consequent need of its deep placement in the soil at an early stage does not seem to have been appreciated in the past. Broadcast dressings of phosphate on the surface of the field would usually be ineffective, and particularly for a deep rooted crop like cotton, deep application of phosphate has to be studied before any generalisation can be made regarding its usefulness or otherwise.

Agricultural practices. Variation in some of the agricultural practices under which the crop is raised is likely to affect its response to manuring. Factors whose modification is feasible in practice should, therefore, be incorporated in manurial trials. Date of sowing is one such factor. While it is determined entirely by the onset of rains in dry areas, its variation has recently assumed prominence in irrigated areas owing to the finding of Dastur (1941) that cotton sown about three weeks to a month later than normal and with a closer spacing escapes *tirak* (bad opening of bolls). Such late sown cotton is less vigorous but this loss in vigor is compensated by the larger number of plants per unit area. Its reaction to manuring may also be different. Manuring of cotton in the irrigated tract, thus, requires to be studied in conjunction with the date of sowing and spacing.

Moisture supply is perhaps the chief factor affecting the response of cotton to manuring. In dry areas it is beyond control, being dependent upon rainfall; but for irrigated cotton a more liberal irrigation is likely to increase the response of the crop to a given quantity of nitrogen. An indication to this effect was obtained in some experiments carried out at Sri Ganganagar in Gang Canal Colony in Bikaner State. It is, however, extremely unlikely that extra water will be available to cotton growers in canal irrigated areas, and consequently a comparison of different doses of irrigation together with different levels of nitrogen does not seem to be of any immediate practical interest.

The effect of cultivation, both preparatory and interculture, on crop growth has received considerable attention in the past. Various implements have been devised to correct the alleged defects of the traditional methods of cultivation. It must be admitted, however, that much of this interest in cultivation was based on theoretical considerations, and at least as far as cotton is concerned whatever critical experimental data are available show that even considerable variations in the method of cultivation do not have an appreciable effect on the crop or its yield (Ramanatha Ayyar and others, 1940). Experiments at Indore have shown that the only function of interculture is to remove weeds which compete with the crop for nutrition. When the field is free from weeds interculture does not confer any added benefit on the crop. Methods of cultivation need not, therefore, be considered for trial in connection with manuring. Crowther (1939) suggested the study of ridge cultivation in dry cotton areas, but experience at Indore does not indicate any favourable effect from ridging.

Variety of cotton. The variety of cotton to be used in the experiment should be the one most commonly grown in the tract. Where a new variety is likely to prove a strong competitor to the existing one, it is necessary to include both the standard and the new varieties in the trial. Even a comparison between a *desi* and an American variety may thus become desirable. With two varieties, it is convenient to sow a whole sub-block with the same variety. This arrangement will moreover minimise the competition between neighbouring plots, if the two varieties differ markedly in their growth habit or in the size of the plants.

These are some of the more important factors that have a bearing on the problem of manuring cotton. While it is desirable to try as many factors as possible simultaneously, there is clearly a limit to the number of factors that can be efficiently incorporated in a single experiment. In preparing experimental designs, a set of factors most likely to influence manuring must, therefore, be selected on the strength of the knowledge of agricultural conditions and previous results in a given tract. For making a start, two lay-outs are suggested here, one for the irrigated tract of Punjab and Sind and the other for the dry area of peninsular India.

I. *Irrigated cotton* (Punjab, Sind). The following factors appear most suitable for trial:—

(*a*) Four levels of nitrogen (0, 30, 60, 90 lbs. per acre).
(*b*) Two kinds of nitrogen (1. ammonium sulphate ; 2. an oil cake, or F.Y.M.).
(*c*) Two times of application (1. early ; 2. at flowering).
(*d*) Two dates of sowing (1. normal ; 2. late).
(*e*) Two spacings (1. normal ; 2. close).

In Sind, comparison between two varieties (1. Sind Sudhar on the Left Bank and 4F98 on the Right Bank ; 2. M4) is necessary as an additional factor, since M4 is rapidly gaining popularity against the standard varieties Sind Sudhar and 4F98.

The proposed experiment will thus consist of 64 treatment combinations if a single variety of cotton is grown and twice this number if two varieties are to be compared. It is convenient to have plots of one variety sown on the same date located side by side and for this reason each replicate should be divided into sub-blocks with a common variety and sowing date. There will then be 32 plots in each sub-block. To reduce the size of the sub-blocks for increasing their statistical efficiency, confounding of certain high order interactions may be resorted to. A plot size of 1/100 to 1/50 acre is suggested. With 128 plots to a replicate, at least two replicates should be laid out ; but with 64 plots three replicates would be preferable.

Rain-fed cotton. An experiment consisting of the following three factors is proposed :—

(*a*) Four levels of nitrogen (0, 20, 40, 60 lbs.).
(*b*) Two kinds of nitrogen (1. ammonium sulphate ; 2. groundnut cake).
(*c*) Two methods of applying manure (1. broadcasting ; 2. drilling close to the seed furrow).

The lay-out is smaller because of the smaller number of factors whose variation is likely to affect the response to manuring under dry conditions. The manure should be applied either at sowing or soon after sowing, except in Gujerat and in Nagpur where the application might be delayed without risk up to three or four weeks after sowing. Plots 1/100 to 1/50 acre in size are recommended for this experiment also, but with only 16 treatments, sub-divisions of a replication into smaller blocks is not necessarily advantageous. Where facilities are available for conducting larger trials, variation in spacing, that is, in the number of plants per unit area, is suggested as an additional factor to explore the possibility that with the additional supply of nitrogen available a larger plant population might be supported profitably in a given area.

In addition to yield data, it would be desirable to take developmental observations on the experimental crop. Observations on growth and vigour, on the constitution of yield (number of bolls, their distribution on the plant, boll weight), the rate of arrival of the crop and ginning outturn are likely to provide information helpful in understanding yield differences between treatments and might suggest modifications of practical value. It is necessary to adopt suitable sampling technique for taking such observations so that the results can be submitted to a valid statistical examination.

In selecting fields for the lay-out, it should be remembered that the results must have a general applicability, to justify the labour and expenditure involved in conducting these elaborate experiments. The type of soil should be representative of the tract and fields with an extremely high fertility, a condition special to experiment stations and Government Farms, should be avoided. It is particularly advantageous to carry out the experiment simultaneously in good and poor fields at each centre. This will bring out the relation between soil fertility and response to manuring.

A programme of coordinated manurial trials on these lines has since been carried out on rainfed cotton at different experimental farms in peninsular India and the results are discussed in the next chapter.

To carry to the cotton grower the results of agricultural research, trials on his own land and under his own conditions for verifying and demonstrating the findings from experiments conducted at research stations is an essential step. No agricultural tract is so uniform that conclusions derived from a few well conducted experiments may be recommended for general adoption over the whole tract. There are within any tract broad differences in one or more features of agricultural significance such as class of soil, besides local differences as in soil fertility or the presence of salinity. Good fertile fields and poor fields commonly occur side by side in the same village and patches of saline soil are intermixed with normal soil. In order to make manurial recommendations applicable not only for a district as a whole but also for the different special conditions existing within the district, a number of simple trials scattered over the whole district and laid out on selected fields provide the only means. Trials of this kind have not received any serious attention in the past, mainly on the ground that the cultivator is not capable of undertaking them. It is hardly to be expected that the cultivator can carry through the trial by himself according to instructions received from the agricultural department. All that is needed is his co-operation in providing suitable land and the required labour, while the department must assume the responsibility for supervision. Once a beginning is made by assuring the grower that he will not suffer a loss and he is made to see the real purpose of the trial, increasing assistance and a more intelligent interest in the trials on his part will be forthcoming and the need for departmental supervision will be correspondingly reduced. It appears that the difficulties of conducting such trials have been far too much exaggerated.

Under rain-fed conditions, groundnut cake has proved to be the most promising source of nitrogen from past trials. Extensive trials should, therefore, be carried out in rain-fed areas with the principal object of determining the most profitable dose of nitrogen applied as cake.

Quantities of nitrogen suggested for trial are 0, 20, 40 and 60 lbs. per acre (20 lbs. N =250 lbs. of the cake). Probably the most suitable form of the trial would be to select a number of representative localities, say 20 or more per district, and lay out four blocks of four plots each, in each locality. The blocks may be situated in different fields, but it would be desirable to select the fields in regard to their fertility, two of the fields being of good fertility and the other two of relatively poor feritilty. Plots should be of uniform size and shape. For statistical efficiency plot size need not exceed 1/40 acre ; but there can be no objection whatever to larger plots if these are considered preferable for other reasons such as agricultural convenience or for serving as a visual demonstration. The only point to bear in mind is that any reduction in the number of blocks in order to be able to handle plots of a large size is undesirable. Long plots with a length/breadth ratio of 5 or more, are recommended. The treatments should be freshly randomized for each block. The cake should be applied at sowing time, except in Gujerat and Nagpur, where it might be added 3 or 4 weeks later. Other items of cultivation should strictly follow accepted local practices. In fact, this must be observed as a general rule in all experiments. Its importance is unfortunately not realized sometimes, and in attempting to increase uniformity, artificial conditions are unnecessarily introduced into the trial and its representativeness impaired. Hand sowing of seed at regular spacing in place of the usual drilling by bullock-drawn implements may be quoted as an example of such undesirable modifications.

Similar trials may be carried out in the irrigated tract to determine the optimum dressing of ammonium sulphate, since results are available only for this form of nitrogen. The doses suggested for trial are 0, 25, 50, 75 lbs. of nitrogen per acre. An additional dose of 100 lbs. may also be included. The dressings should be given at intensive flowering which has been found to be the optimum time for application of the fertilizer to irrigated cotton. These trials might be restricted to land free from any considerable degree of salinity, since it has been shown (Dastur, 1941) that cotton does not respond to artificial nitrogen on saline soil and this was borne out by the results of past manurial trials. In other particulars, the method of carrying out the trial should be the same as that recommended for unirrigated cotton.

The importance of maintaining detailed records of the various items connected with the trials cannot be over-emphasized. Part of the labour and expense involved in carrying out the trials would be wasted, if some of the information sought for cannot be extracted from the results owing to vague or incomplete records. Collection of data in respect of the following details is recommended :—

(1) Name of cultivator.
(2) Survey number of field, village, tehsil, district.
(3) Type of soil (alluvial, black cotton, red etc.) and fertility level (good, medium or low).
(4) Previous crop and its manuring.
(5) Plan of layout including dimensions of plots, their arrangement etc.
(6) Agricultural operations performed during the experiment such as date and method of sowing, seed rate, variety, dates of irrigation, if any, etc.
(7) Rainfall recorded at the nearest station, daily or monthly, and notes on other seasonal conditions, *e.g.* dates and severity of frost.
(8) Notes on initial and final stand with causes of mortality, actual plant count in sample areas, if possible ; notes on diseases and pests.
(9) Dates of picking and weight of seed cotton per plot per picking in standard units, carefully assessed.
(10) Market price of seed cotton, of manure and of any charges incidental to manuring.
(11) Ginning percentage.

The experimental schemes should preferably be drawn up on standard forms with space provided for entering the information asked for.

For a correct estimate of profit resulting from manuring cotton, it is necessary to take into account the additional profit made through the residual effect of the manure on subsequent crops. At the end of the manurial trial on cotton, the trial plots might, therefore, be uniformly sown with the next crop in the local rotation and its yield and money value recorded.

The programme of experimental work proposed here is clearly intended for a beginning. As the work advances, modification and expansion of the experiments will become necessary. Arbitrary alterations are, however, highly detrimental to the efficiency of the trials, and changes in the programme once adopted should be made only after a careful examination of all relevant results together. A possible criticism of the programme suggested would be that with the staff and facilities available, experimental work on this scale cannot be undertaken by most departments of agriculture. It is partly a question of training existing staff and adapting existing facilities for work of this nature ; but above any other consideration, if the pressing need of increasing our agricultural yields, particularly of cash crops like cotton, and the magnitude of the task involved are appreciated, there can be no hesitation in providing adequate staff and facilities to ensure that the objective is achieved without serious delay.

REFERENCES.

1. Crowther, F. ... ... (1939) *Agric. and Livestock in Ind. 9*, 401.
2. Crowther, F., and Ahmed Mahmoud. (1935) *Tech. Bull. Roy. Agric. Soc. Egypt*, No. 22.
3. Crowther, F., Tomforde Adolf, and Ahmed Mahmoud. (1936) *Tech. Bull. Roy. Agric. Soc. Egypt*, No. 26.
4. Dastur, R. H. ... ... (1941) *I. C. C. C. 2nd Conf. of Sci. Res. Workers in India*, Cotton Agriculture, Paper No. 9.
5. Kalamkar, R. J. ... ... (1942) *Curr. Sci. 11*, 190.
6. Lewis, A. H. ... ... (1941) *J. Agric. Sci. 31*, 295.
7. Ramanatha Ayyar, V., S. Sundaram, and N. C. Tirumalachari. (1940) *Madras Agric. J. 28*, 69.
8. Stewart, A. B. ... ... (1947) Report on Soil Fertility Investigations in India with Special Reference to Manuring. Indian Council of Agricultural Research, New Delhi.

CHAPTER V

NEW SERIES OF MANURIAL TRIALS ON RAINFED COTTON.

Past manurial trials on cotton in India have shown that cotton, both irrigated and rainfed’ gives a consistent response to nitrogenous fertilisers, specially ammonium sulphate, and organic manures like oilcakes of groundnut, toria (mustard) and neem (margosa), except under conditions of soil salinity or inadequate rainfall. There was also definite evidence that the level of soil fertility which is an integrated result of all known and unknown factors which determine yield, influences the degree of response to nitrogen in such a way that under conditions of high yield, the response to a given quantity of nitrogen is also high and *vice versa*. The need for further experimentation on a comprehensive and coordinated plan in order to determine the optimum quantities of nitrogen for application and precise specification of the conditions governing the response of cotton to nitrogen was stressed. A suitable programme of experimental work with this end in view was proposed in the last chapter. Model layouts for such experiments on irrigated and rainfed cotton were also indicated. Schemes for conducting experiments on these lines on irrigated American cotton in Sind and Punjab were sanctioned by the I.C.C.C. and the trials had actually progressed for two years in Sind when the partition of the country came. This scheme has now been revived for East Punjab and was approved by the Committee at its meeting in October 1949. Coordinated experiments on rainfed cotton on the lines recommended in the last chapter were commenced in 1943-44 at various research farms in the cotton tracts of peninsular India with the voluntary cooperation of the agricultural departments concerned and were continued upto 1947-48. The results of this series of experiments are summarised in the present chapter.

The most serious drawback of past trials, as brought out in the review, was that a range of nitrogen doses sufficiently wide to provide data for the determination of optimum doses was not tried, the quantities of nitrogen applied being limited to 40 or 50 lb. per acre on the view that larger doses would be uneconomic. Experimentation should, however, not be restricted by such considerations which tend to anticipate the result. Economics of the manuring of cotton is subject to a continual change, depending as it does upon the prevailing prices of cotton and cost of manure, apart from the rate of increased yield obtained by manuring. The correct approach to the study of the economics of manuring is to determine through adequately planned manurial trials the agricultural relationship between the quantity of manure and the increase in yield resulting therefrom under a given set of cultivation conditions. Once this relationship is established with requisite precision, it is a simple matter to calculate with its help profits to be expected from a given application of nitrogen as also the optimum or most profitable dose of nitrogen, with reference to any given cost of manure and price realised for cotton. The agricultural relationship between quantity of nitrogen and the resulting increase in yield can be best expressed statistically for this purpose as a polynomial curve, termed the response curve, of the second or higher degree. It is obvious that response to nitrogen can not be assumed to be linear *i.e.*, proportional to the quantity of nitrogen except perhaps over a narrow range of small dressings. The law of diminishing returns comes into operation with larger doses and the response curve tends to bend downward as doses of nitrogen are increased. Within the range of experimental doses usually considered sufficient for a precise determination of this curve, a second degree parabola may be regarded as its adequate representation. Sukhatme (1941) has used this form of the response curve in studying the economics of manuring of paddy. Failure to appreciate this basic or primary objective of manurial experiments resulted in past trials in the application of doses which were too low to give conclusive results, and is also responsible for the criticism which is sometimes heard against the trial of large and apparently uneconomic doses in the modern trials.

The present series of trials was planned to determine the response curve for nitrogen applied to rainfed cotton on black soil. As recommended in Chapter IV, critical information was also sought on two other items, *viz.* (1) the relative efficiency of nitrogen in the form of ammonium sulphate and groundnut cake and (2) the comparison between the application of manure by broadcasting on the surface and drilling it into the soil. To study the response of cotton to nitrogen under varying conditions of soil fertility, the trials were simultaneously located on two or three fields known to have different levels of fertility, at each station.

Layout and distribution of the experiments.

In pursuance of the above objectives of these trials, each experiment was planned to include treatment combinations for the following factors :

(1) Kind of nitrogen : ammonium sulphate, groundnut cake.

(2) Method of application : drilling, broadcasting.

(3) Doses of nitrogen : usually four and ranging from 0 to 60 lb. nitrogen per acre in the first year ; the range was increased to 80 lb. nitrogen per acre on good land and upto 100 lb. per acre on very fertile fields in subsequent years, as lesser quantities were found to be inadequate for determining the true shape of the response curve on such land.

Besides nitrogen in the above two forms *viz.* ammonium sulphate and groundnut cake, neem cake was a third form included in trials at Koilpatti in Madras Province. It was found that this cake was as good as ammonium sulphate or groundnut cake in both seasons, 1944-45 and 1945-46, in which it was tried. Nitrogen was applied at or soon after sowing in all trials, except that in the trials in Hyderabad State a broadcast application about a fortnight before sowing was included as an additional treatment. The results obtained were, however, conclusive in showing that application at sowing was more effective than this earlier application. All trials were laid out in randomised blocks, usually with three replications and contained 16 to 30 treatment combinations. The layout plans were settled in consultation with the author.

Fifteen experiment stations scattered in different cotton tracts of peninsular India and shown in fig. 1 co-operated in project and carried out a total of 89 trials over a period of five years, 1943-44 to 1947-48. The distribution of these trials is shown in table I.

TABLE I

Distribution of co-ordinated manurial trials on rainfed cotton.

Region and station	Number of trials.					
	1943-44	1944-45	1945-46	1946-47	1947-48	Total
Madhya Bharat						
Indore	2	2	2	2	..	8
Madhya Pradesh						
Akola	2	2	2	2	..	8
Khandwa	..	..	2	2	2	6
Bombay.						
Baroda	..	..	1*	1*	..	2
Surat	..	1*	2	2	2	7
Jalgaon	1	2	2	2	..	7
Dhulia	1*	..	..	..	..	1
Hyderabad						
Nanded	2	3	2+1*	3	..	11
Latur	3	2	2	2	..	9
Madhol	3*	3*	3*	3*	..	12
Madras						
Koilpatti..	3	2	2	..	..	7
Guntur	1	1	1	..	..	3
Nandyal	1	1	1	..	..	3
Hagari	2*	..	..	..	..	2
Coimbatore	1	1	1	..	..	3
Total ..	22	20	24	19	4	89

For the present study which relates to the black soil, 19 trials marked with an asterisk in the above table were omitted as not being representative. It may be recalled from the review of the past trials that response to manuring is poor or even adverse under conditions of scanty rainfall and consequently centres with such rainfall are not suitable for manurial experiments. Trials at Dhulia and Hagari have been omitted for this reason and were, in fact, discontinued after the first year. The experiments at Baroda were located on gorat soil and not on black soil. Similarly, at Madhol in Hyderabad State the experimental land was not typical black soil, but a much lighter red loam. The first trial at Surat in 1944-45 was vitiated owing to a very late application of manure on account of continuous rain and a trial at Nanded in rich field in 1945-46 was spoiled by an attack of fussarium wilt. Barring these cases, the remaining 70 trials were included in the present analysis. The annual rainfall at different stations during the years in which these 70 trials were carried out there, is shown in table II.

TABLE II.

Annual rainfall at experiment stations where co-ordinated manurial trials were laid.

Station.	1943-44	1944-45	1945-46	1946-47	1947-48
Indore	35·54	58·56	42·05	55·33	37·45
Akola	30·22	46·06	41·29	32·53	..
Khandwa	..	..	21·30	42·86	19·76
Surat	..	..	64·97	67·35	29·95
Jalgaon	33·48	40·51	29·18	41·77	..
Nanded	38·61	36·80	27·00	33·39	..
Latur	39·58	33·86	33·38	24·66	..
Koilpatti	17·77	38·71	29·84	..	..
Guntur	33·80	33·92	40·34	..	..
Nandyal	11·91	26·34	38·34	..	..
Coimbatore	17·92	32·80	29·25	..	..

It will be seen that the annual rainfall ranges mostly between 25 and 45 inches at different stations and this represents the usual rainfall under which most of the rainfed cotton is grown on black soil.

Method of statistical analysis and results.

The objects of the present analysis are to obtain from the entire series of trials critical information concerning,

(1) The effectiveness of the two forms of nitrogen, *viz.*, ammonium sulphate and groundnut cake, in comparision to each other.

(2) The effectiveness of drilling the manure in comparison to the usual method of broadcasting, and

(3) The rate of response of cotton to nitrogen.

The influence of rainfall and soil fertility on these three factors has also been studied. Finally the economics of manuring has been examined in relation to soil fertility which has been shown to have a profound effect on the character of the response curve and formulae have been developed predicting the magnitude of response to a given dose of nitrogen and the optimum dose of nitrogen at any given level of fertility of the soil.

Corresponding to each individual trial an analysis of variance was carried out to test the statistical significance of the different factors including the linear and second degree components of the response curve. Appropriate mean values and the linear and quadratic coefficients of the response curves were also calculated. It was generally observed that there was no interaction between the different factors in a trial, or, in other words, these factors, *viz.*, the relative effectiveness of the two forms of nitrogen, the comparison between the two methods of application and the shape of the response curve, behaved as being statistically independent of one another. The values for the different factors averaged over all trials together with their standard errors calculated from variation between the trials are shown below.

TABLE III

Average effects of different factors over all trials.

Factor.	Mean values in lb. seed cotton per acre.	S. E.
(1) Difference in response to ammonium sulphate and groundnut cake	14·9	9·1
(2) Difference in response to drilling and broadcasting ammonium sulphate	1·6	7·7
(3) Difference in response to drilling and broadcasting groundnut cake	12·7	6·7
(4) Average rate of response to nitrogen, the linear coefficient of the response curve	2·465	0·240
(5) Average rate of change in the linear coefficient or the quadratic coefficient of the response curve	—·0259	·0042

On the average of all trials there was no significant difference between the two forms of nitrogen, ammonium sulphate and groundnut cake, although the numerical value of the difference is in favour of the former. Method of application also made no difference as far as ammonium sulphate was concerned, but for groundnut cake drilling appeared to give a small increase in yield over broadcasting, the difference approaching significance as judged by its standard error. Both the linear and quadratic coefficients of the average response curve were highly significant, the quadratic coefficient being negative as it should be for a typical yield curve.

Each of these factors showed appreciable variation among different trials both in regard to the numerical magnitude of the effect and its statistical significance. Consequently the average results given above cannot by themselves provide a very useful basis in making practical recommendations on manuring. It is desirable to investigate the relationship between the effects observed in individual trials and the conditions of the trials in so far as these conditions are measurable. If such a relationship is found to exist, the effects to be expected under any given set of conditions could be predicted and this would form a reliable basis for making practical recommendations appropriate to specified conditions. The conditions available for study were the annual rainfall and soil fertility. Of course, in addition to total annual rainfall, its distribution over the season is also important in influencing yield and response to manure; but the examination is here confined to the effect of the total annual rainfall. With regard to soil fertility the average yield of a trial is employed as a measure of fertility. Yield is clearly the best index of soil fertility; but the reason for using the average yield of the whole trial in preference to that of the unmanured plots alone is a statistical one, inasmuchas comparisons based on the latter yield are shown to be biased (Yates, 1935). The variation in the range of nitrogen dressings applied in the different trials introduces a complication in using the average yield of a trial as a measure of fertility; but a re-examination of the data by grouping the trials according to the range of nitrogen dressing applied showed that the conclusions were not affected by such variation.

A joint regression of the effect of each manurial factor on soil fertility and annual rainfall was calculated from which the separate contribution of soil fertility and rainfall to the combined relationship was further isolated. Considering that the trials were spread over different stations and different seasons and were also conducted simultaneously in different fields at the same station, three types of regression analyses are available. These are (1) regression within years within stations which would measure the relationship with soil fertility alone under identical rainfall and would thus be the best measure of this relationship; (2) regression between years within stations, which would involve seasonal variation at the same station plus the average difference in soil fertility in different seasons at the same station resulting from a change of fields, on which the trials were located in different seasons, and (3) regression between stations which involves average differences between stations and include the characteristic soil and rainfall differences between different stations. The second regression may be expected to bring out the influence of rainfall rather well since the average soil differences between seasons at the same station are not likely to be large while the third regression might not show any pronounced effect of either soil or rainfall owing to the relatively homogeneous conditions that the soil fertility and annual rainfall at the different stations included in the present study represent.

The results of the regression analysis are shown in table IV.

TABLE IV.

Influence of fertility and rainfall on manurial comparisons

Analysis of variance for regression.

Due to	Within years within stations		Between years within stations		Between stations	
	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.
		Ammonium Sulphate—Groundnut cake.				
Joint regression on fertility and rainfall	..	..	2	1822	2	14688
Linear regression on fertility alone ..	1	47867**	1	10	1	20698
Balance due to regression on rainfall..	..	..	1	8686	1	8672
Residual	81	5257	25	1955	8	18876
		Drilling—Broadcasting (Ammonium Sulphate)				
Joint regression on fertility and rainfall	..	..	2	6256	2	258
Linear regression on fertility alone ..	1	264	1	11048	1	818
Balance due to regression on rainfall..	..	..	1	2004	1	194
Residual	80	2772	21	6148	8	2617
		Drilling—Broadcasting (Groundnut cake)				
Joint regression on fertility and rainfall	..	..	2	1008	2	1149
Linear regression on fertility alone ..	1	1997	1	979	1	1825
Balance due to regression on rainfall..	..	..	1	1088	1	474
Residual	80	2280	21	8655	8	4188
		Linear coefficient of response curve				
Joint regression on fertility and rainfall	..	..	2	30.58	2	24.12
Linear regression on fertility alone ..	1	14.99**	1	54.85**	1	46.27**
Balance due to regression on rainfall..	..	..	1	6.21	1	1.98
Residual	81	1.55	25	2.15	8	8.81
		Quadratic coefficient of response curve				
Joint regression on fertility and rainfall	..	..	2	0.00282	2	0.00071
Linear regression on fertility alone ..	1	0.00018	1	0.00879**	1	0.00006
Balance due to regression on rainfall..	..	..	1	0.00086	1	0.00177
Residual	81	0.00141	25	0.00094	8	0.00154

** Significant on 1% level

In order to further investigate the effects of soil fertility on these factors, mean values of responses to the various factors corresponding to three different levels of fertility are shown in table V. Their standard errors were calculated from variation between experiments within each group. For the construction of this table, all trials with an average yield upto 250 lb. per acre were classed together arbitrarily and this group was regarded as representing low fertility. Trials with yields between 250 and 500 lb. formed a group representing medium fertility and trials with yield above 500 lb. constituted a high fertility group. Conclusions derived from this analysis are discussd below.

TABLE V.

Manurial comparisons for three fertility groups.

Group	Number of trials	Amm. sulphate—G. nut cake		Drilling—Broadcasting				Response curve.			
		Mean dif. lb. per acre.	S.E.	Amm. Sulphate		G. nut cake		Linear coefficient		Quadratic coefficient	
				Mean dif lb. per acre.	S. E.	Mean dif lb. per acre.	S. E.	Mean	S. E.	Mean	S. E.
1. Low fertility ..	13	—11.4	7.2	— 1.7	5.1	0.7	5.1	0.840*	0.274	—0.0052	0.0041
2. Medium ferility	30	2.1	6.1	— 1.7	13.6	6.7	9.7	1.928**	0.322	—0.0361**	0.0031
3. High fertility ..	27	41.8	21.6	6.3	7.6	23.8	12.5	3.845**	0.283	—0.0243**	0.0051
All trials ..		14.9	9.1	1.6	7.7	12.7	6.7	2.465**	0.240	—0.0259**	0.0042

** Significant on 1% level
* ,, ,, 5% ,,

(*a*) Ammonium sulphate *vs.* groundnut cake.

In the comparison between the two forms of nitrogen, ammonium sulphate and groundnut cake, the effect of soil fertility was very clearly brought out in the first regression analysis, *viz.* within years within stations in table IV. The nature of this effect will be seen from the mean values of the difference between the two manures corresponding to three different levels of fertility shown in table V. It is seen from table V that the difference between the response to ammonium sulphate and groundnut cake tended to increase with soil fertility; but it was only in the high fertility class that the difference in favour of ammonium sulphate was almost significant. It may be concluded that both forms of nitrogen produce an almost equal response, except on highly productive soil where ammonium sulphate might prove superior.

(*b*) Broadcasting *vs.* drilling.

In regard to the method of application, neither fertility nor rainfall showed any evidence of association with the difference between broadcasting and drilling in the case of either form of nitrogen in the regression analysis in table IV. For ammonium sulphate the average difference between the two methods over all trials was negligible and when the trials were grouped according to fertility in table V, the mean difference was small and not significant for any group. It would thus seem that for ammonium sulphate broadcasting is as good as drilling and would be preferred to the latter on account of its simplicity and saving of labour. With groundnut cake, there was an indication of a slight superiority of drilling over broadcasting both from the average difference over all trials as also from the differences for the three fertility groups in table V. It would be seen that difference in favour of drilling tended to increase with the soil fertility and in the high fertility group the difference was very nearly significant. Groundnut cake when broadcast has been observed to affect the stand of the crop adversely and the stand is better when the cake is drilled in a furrow at a short distance from the seed furrow. It may be concluded that drilling the cake is a safer practice than broadcasting it and the former method might prove definitely more advantageous on land of high fertility.

(*c*) Response to nitrogen.

In regard to the relationship between quantity of nitrogen and increase in yield or the response curve, all three regression analyses brought out the dominant role played by soil fertility in determining the rate of response to nitrogen and the linear and quadratic coefficients in table V and the corresponding response curves in figure 4 for the three levels of fertility demonstrate the nature of the difference. One aspect of this difference is that the average rate of increase in yield per unit qantity of nitrogen was larger on land of higher fertility. This means that the same quantity of nitrogen will bring about a larger increase in yield if applied to more fertile land than to poor land. In the low fertility group the average rate of increase in yield per unit application was small. It was over twice as high in the medium fertility group, while in the high fertility group it was double of that in the medium group. The significance of the change in the quadratic coefficient in relation to fertility is similar. The curvature of the response curve or the fall in response to larger doses of nitrogen is less on more fertile land. Consequently large quantities of nitrogen may be more profitably applied under conditions of high fertility than under conditions of medium or low fertility. These points were well brought out by an examination of the response curves of individual trials. Under conditions of high yield as represented by trials in good fields at Jalgaon, Akola, Koilpatti, etc., the response curves were virtually straight lines with small and non-significant quadratic coefficients even when dressings as large as 100 lb. nitrogen per acre were included in the trials. In other words, in such cases the increase in yield was proportional to the quantity of nitrogen even for such large doses. On land of lower fertility the curves bent downwards rapidly, as in trials at Latur, Akola and Nanded in the medium fertility group indicating a rapid falling off of response with higher doses of nitrogen, or had initially a poor slope as in trials at Indore, Nandyal and Akola in the poor fertility group, which meant that the average rate of increase in yield was low.

The important role played by soil fertility in determining the course of the response curve for nitrogen was thus brought out by the regression analysis and is demonstrated by the typical curves calculated for three fertility levels shown in fig. 4. It was consequently considered desirable that a general equation for the response curve should be developed, which would be capable of giving the appropriate curve at any desired level of soil fertility by substituting in it the numerical measure for the given fertility level. From such an equation, the increase in yield to be expected from a given dressing of nitrogen as also the optimum or most profitable dressing of nitrogen at any particular level of fertility can be calculated easily. With the help of this equation, the study of the economics of manuring could thus be related to soil fertility. This problem is discussed in a later section.

(*d*) Influence of rainfall.

Influence of rainfall on any of the factors discussed above was not evident from the regression analysis except possibly on the linear coefficient of the response curve as shown by the analysis between years within stations in table IV. Heavier rainfall had the effect of decreasing the rate of response to nitrogen. The general lack of the influence of rainfall on other factors may be explained partly by the fact that the rainfall was generally adequate and had a relatively narrow variation among the stations selected for the experiments during the years in which the trials were in progress and partly by the possibility, mentioned earlier, that the distribution of rainfall over the season is more important than the annual total.

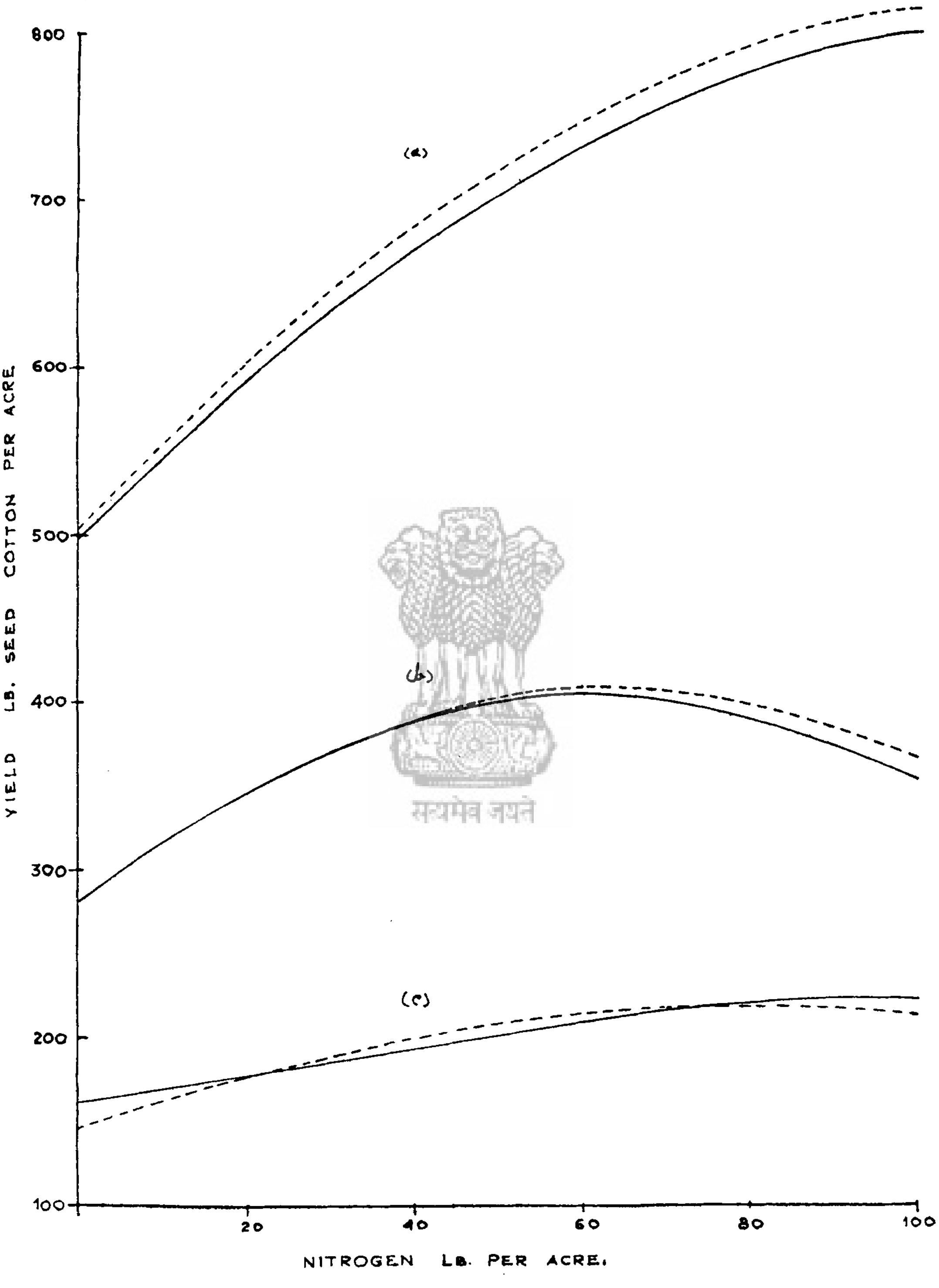


Fig. 4—Response curves for crude yield.

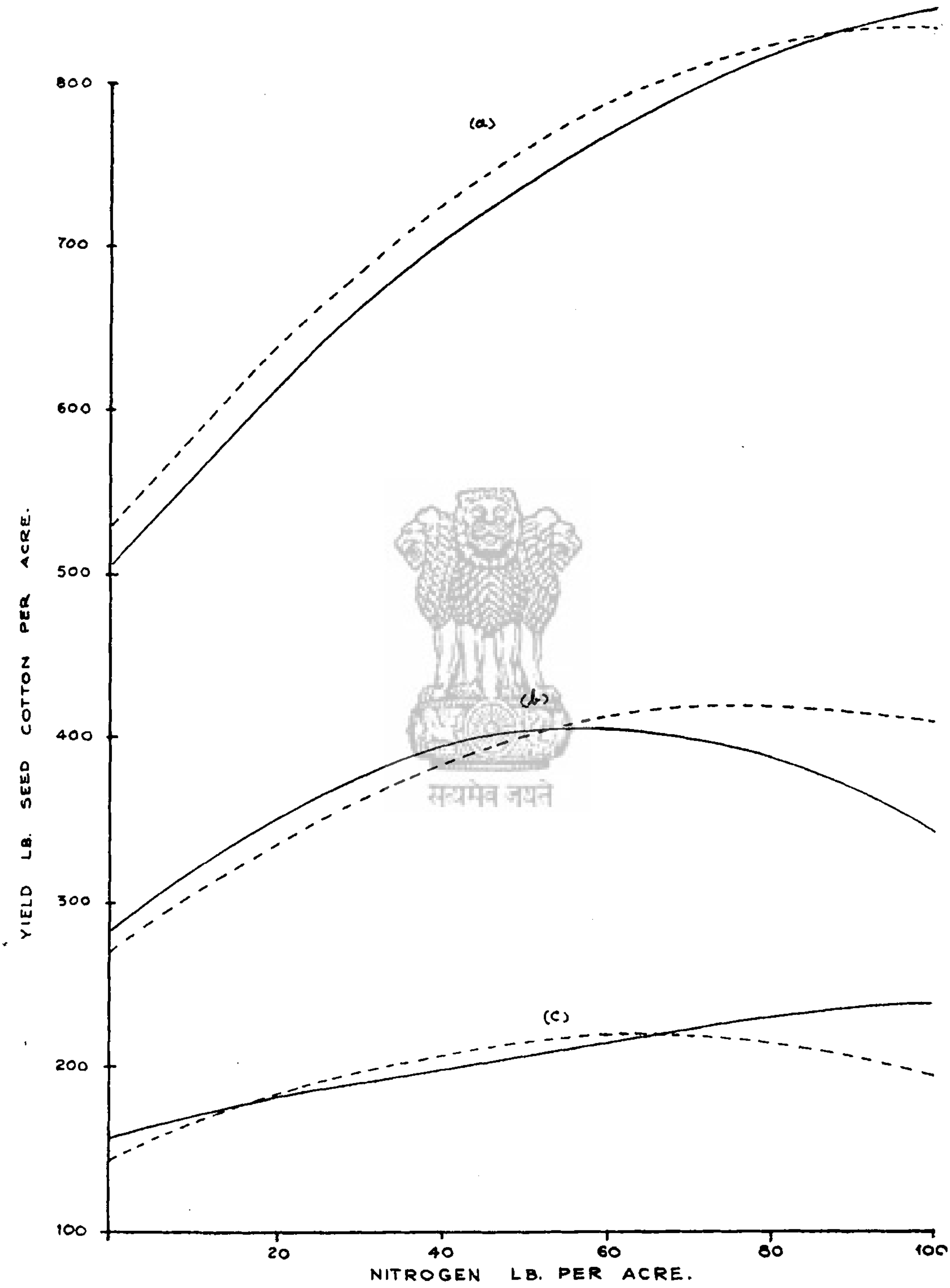


Fig.5 —Response curves for yield adjusted for stand.

सत्यमेव जयते

Adjustment for stand.

Before studying the problem of the economics of manuring, the possibility of the increase in yield due to manuring being affected by differences in stand between the manured and unmanured plots was examined. For this purpose, arrangements had been made for recording a final stand count per plot in all trials and out of the 70 trials included in the present study, these counts were available for 61 trials.

Out of the 61 trials, differences in stand for any of the treatments were significant in 24 trials. In these 24 trials, the manured plots had on the average a stand equal to 93 per cent of the unmanured control. Plots treated with groundnut cake had a slightly lower stand than those with ammonium sulphate. In both manures, stand was apparently better conserved by broadcasting than by drilling the manure, but this effect was at least partly ascribable to the faulty method of drilling employed in the earlier trials, *viz.* drilling the manure in close contact of the seed. This effect was particularly noticeable with groundnut cake and in some of the later trials in which the cake was applied in a separate furrow at some distance from the seed furrow, the stand by drilling was better than by broadcasting the cake. The analysis of variance for yield and the mean yields for different treatments were adjusted for covariance between yield and stand by the usual procedure of the analysis of covariance in each of the 61 trials. It was noticed that the adjustment had the effect of slightly lowering the yields of no manure plots and of increasing the yields of manured plots. Response curves were fitted to the adjusted yields as well as to crude or unadjusted yields. Yields in these trials and average curves for both adjusted and unadjusted yields were calculated for the three fertility levels after grouping the trials in the manner explained earlier. The two types of curves are shown in Fig. 5 and agree so closely as to lead to the conclusion that the disturbance in stand resulting from the application of manure did not produce any significant effect on the course of the response of yield to nitrogen. This conclusion has enabled the present study to be based on the original unadjusted yield data throughout without the results being vitiated by the influence of differences in stand.

Economics of manuring.

The importance of planning manurial trials in such a way as to provide adequate data for studying the economics of manuring has been emphasized in Chapter III and the present series was planned with this object in view. The results discussed above have clearly shown the necessity of studying this problem in relation to soil fertility, since this factor has been shown to have a profound influence on the rate of response to nitrogen and would have a corresponding effect on the economics of manuring.

The statistical procedure by which response curves can be employed in the study of the economics of manuring has been explained in Chapter III. The expected yield of seed cotton in lb. per acre corresponding to a given dose of nitrogen x, is given by the following equation for the response curve,

$$Y = a + bx + cx^2$$

where a is the yield of seed cotton per acre without application of nitrogen and $bx + cx^2$ is the increase in yield or response expected from the application of x lb. nitrogen per acre. If p represents the price per lb.of seed cotton, the additional money return per acre from the application of x lb. nitrogen would be $p\ (bx + cx^2)$. Further if q is the cost per lb. of nitrogen, the total cost of manure would be qx and the expected profit would be given by the expression

$$p\ (bx + cx^2) - qx$$

The dose of nitrogen which would give maximum profit, termed the optimum dose, can be calculated from the expression by differentiating it and then equating to zero. Thus X, the optimum dose of nitrogen, is given by the formula,

$$X = \frac{1}{2c}\left(\frac{q}{p} - b\right)$$

Corresponding to any response curve for which the values of the coefficients b and c are known, the optimum dose at varying levels of the ratio $\frac{q}{p} = \frac{\text{cost of nitrogen per lb.}}{\text{price of seed cotton per lb.}}$ can be worked out from this formula. From pre-war data of the cost of ammonium sulphate and groundnut cake and prices of seed cotton at various experimental farms, this ratio was found to range from 1 or 1·5 to 5·0. At current rates for the fertiliser and seed cotton, the ratio may be taken to vary from 2·5 to 3·5.

The above method of calculating the optimum dose of nitrogen was applied to the three response curves representing the three fertility groups (Fig. 4) and the results are shown in table VI.

TABLE VI.

Optimum quantity of nitrogen lb. per acre.

	Ratio $\frac{q}{p} = \frac{\text{cost of nitrogen per lb.}}{\text{price of seed cotton per lb.}}$				
Fertility group.	1	2	3	4	5
Low	29	..	..	..	..
Medium	45	31	17	3	..
High	100	79	59	38	17

Assuming the current value of the ratio $\frac{q}{p}$ to be in the neighbourhood of 3, an application of 20 lb. nitrogen per acre to cotton on land of medium fertility and 60 lb. nitrogen per acre on land of high fertility would be expected to be most profitable dressing. On poor land, application of nitrogen would not yield any profit.

This illustration of the influence of soil fertility level on the economics of manuring brought out with the help of response curves appropriate to the three arbitrarily chosen levels of fertility emphasises the value and usefulness of developing a single general equation from which the economics of manuring at any desired level of fertility may be worked out. The approach employed for obtaining such an equation is described below.

The basic equation of the second degree for predicting yield for a given dose of nitrogen from the results of a suitably planned trial is

$$Y = f + B\xi_1 + C\xi_2 \qquad (1)$$

where f is the average yield of the trial and represents a numerical measure of fertility in the sense in which this measure has been defined in the present article; ξ_1 and ξ_2 are first and second degree orthogonal or statistically independent functions of x, the given dose of nitrogen, and B and C are the linear and quadratic regression coefficients of the orthogonal polynomial fitted to the data (Fisher, 1946). Then Y is the predicted yield per acre for an application of x lb. nitrogen per acre.

Since the regression coefficients B and C in the above equation have been shown to be closely associated with fertility, these coefficients may be replaced by their regression functions in terms of fertility. These functions may be expressed as

$$B' = \bar{B} + b'(f - \bar{f})$$

$$C' = \bar{C} + c'(f - \bar{f})$$

These regression equations were calculated from the data for the 70 trials and gave the following values.

$$B' = 0\cdot0056\,f - 0\cdot123$$
$$C' = -0\cdot000027\,f - 0\cdot0134$$

Substituting these values of B' and C' in the equation of the response curve in place of coefficients B and C, we get,

$$Y = f + (0\cdot0056\,f - 0\cdot123)\xi_1 + (-0\cdot000027\,f - 0\cdot0134)\xi_2$$

It will be recalled that the number and range of doses of nitrogen used in the different trials were not identical and consequently the values of ξ_1 and ξ_2 were not the same for all trials. The mean values of these functions were therefore calculated over all trials and introduced in the above equation which could then be expressed in the following form

$$Y = -4\cdot45 + \cdot76f + (0\cdot0077f + 0\cdot85)\,x - (0.000027f + 0\cdot013)\,x^2$$

This is the prediction formula for yield corresponding to x lb. of nitrogen at the fertility level f. The response to x lb. nitrogen, *i.e.* increase in yield per acre from this quantity of nitrogen, is given by

$$Y' = (0\cdot0077f + 0\cdot85)\,x - (0\cdot000027f + 0\cdot013)\,x^2 \qquad (2)$$

The variance of this response is

$$V(Y') = V(B')\bar{\xi}_1^2, + V(C')\,\bar{\xi}_2^2$$

where

$$V(B') = V(\bar{B}) + V(b')\,(f-\bar{f})^2$$
$$V(C') = V(\bar{C}) + V(c')\,(f-\bar{f})^2$$

These variances can be calculated from the regression of B and C on fertility and variances of $\bar{B}$ and $\bar{C}$ are obtained from variation in the values of these coefficients among the 70 trials.

If p is the price of seed cotton per lb. and q is the cost of nitrogen per lb., then, as shown previously, the profit to be expected from manuring is given as,

$$p\,(\cdot0077f + 0\cdot85)x - p\,(0\cdot000027f + 0\cdot013)x^2 - qx$$

From this expression, the formula for optimum dose of nitrogen may be derived by maximising it. This formula is..

$$X = \frac{\frac{q}{p} - (0\cdot0077f + 0\cdot85)}{-2\,(0\cdot000027f + 0\cdot013)} \qquad (3)$$

The variance of X or the optimum dose is given by the variance of

$$\frac{\frac{q}{p} - B'}{2C'} \qquad \text{so that } V(X) = \frac{V(B')}{4C'^2} + \frac{\left(\frac{q}{p} - B'\right)^2}{4C'^4}\,V(C')$$

We can thus calculate from equation (2) the response to be expected from an application of a given quantity of nitrogen at any particular level of fertility and from (3), the optimum dose of nitrogen corresponding to a desired fertility level. Expressions giving the standard errors of these quantities have also been derived and are shown above. These formulae thus provide a logical and unified approach for studying the economics of manuring in place of the results obtained from an arbitrary grouping of the experimental data in different fertility levels.

By substituting various numerical values for X, the dose of nitrogen, and any desired value for f, the fertility measure, in the general formula (2) above, the yield curve corresponding to a particular fertility level can be drawn. From this formula, the values of response in lb. per acre for $x = 20, 40, 60, 80$ and 100 lb. nitrogen per acre and fertility measures = 194, 363 and 701 lb. average yield per acre which correspond to the average yields of the trials grouped together in low, medium and high fertility groups made earlier, were calculated and are shown in table VII. The standard errors of these predicted responses were also calculated and are included in the table.

सत्यमेव जयते

TABLE VII.

Predicted responses calculated from the general formula in lb. per acre and their standard errors.

Fertility measure. average yield per acre, lb.	Yield without nitrogen	Doses of nitrogen lb. per acre.									
		20	S.E.	40	S. E.	60	S.E.	80	S.E.	100	S.E.
194, low fertility.. ..	143	40	5.7	66	4.8	77	6.1	72	12.9	54	26.1
363, medium fertility ..	272	70	4.1	111	3.5	188	4.8	148	9.0	137	18.8
701, High fertility	529	118	5.3	200	4.5	261	5.7	297	12.2	307	24.4

The corresponding yield curves are shown by dotted lines in figure 4, where these are superposed on the curves drawn from three separate equations derived from the results of trials grouped under low, medium and high fertility. The agreement between the two sets of curves is sufficiently close to serve as a verification of the soundness of the approach adopted for evolving a single common formula applicable to any chosen level of fertility.

The optimum doses of nitrogen at the three specific fertility levels used in the earlier discussion were also recalculated from the general formula (3) and these values together with their standard errors are given in table VIII. These values are comparable with corresponding values calculated from three separate response curves for the three fertility groups and shown in table VI. The two sets of values show a fairly close agreement, as is to be expected. Both tables show that under favourable conditions of prices very high dressings of nitrogen, 80 lb. per acre or more, may be applied with an expectation of maximum profit when the fertility status of the soil is high. At the other extreme manuring of cotton is not likely to be profitable on poor soil except under the most favourable price conditions.

TABLE VIII.

Optimum doses of nitrogen calculated from the general formula and their standard errors.

Fertility measure. average yield per acre, lb.	Ratio q/p = Cost per lb. nitrogen. / price per lb. seed cotton									
	1		2		3		4		5	
	dose	s.e.	dose	s.e.	dose	s.e.	dose	s.e.	dose	s.e.
194, Low fertility	38	7.3	11	12.3	..	..	..	..	..	..
363, Medium fertility	58	5.7	37	4.1	15	6.3	..	..	..	..
701, High fertility	83	9.2	67	6.6	51	4.6	36	4.0	20	5.3

With the help of the general formulae (2) and (3), tables showing responses to be expected from graded applications of nitrogen on land whose fertility may be represented by an average yield 200, 400, 600, 800 and 1,000 lb. per acre and the optimum doses of nitrogen at these fertility levels have been prepared and are shown in tables IX and X.

It should be remembered that the numerical values for fertility levels given in these tables correspond to the hypothetical average yield of a trial in which graded doses of nitrogen have been applied and a second degree polynomial fitted to the yields. In making a practical application of the results, however, these average yields will be unknown and will also not be quite appropriate since it is the value of initial fertility represented by yield without the application of the fertilizer that is required for reference. The no manure yields calculated from the respective yield curves are therefore included in these tables side by side with the average yields.

TABLE IX.

Responses, lb. kapas per acre, expected from graded applications of nitrogen on land with average yield ranging from 200 to 1,000 lb, per acre.

Fertility level lb. kapas per acre.	No manure yield lb. kapas per acre.	Doses of nitrogen lb. per acre.				
		20	40	60	80	100
200	148	41	66	77	73	55
400	300	69	119	149	161	153
600	452	98	172	224	252	257
800	604	126	224	295	337	351
1000	756	155	278	369	428	455

The corresponding yield curves are shown in figure 4.

TABLE X.

Optimum doses of nitrogen lb. per acre on land with average yield ranging from 200 to 1,000 lb. per acre.

Fertility level, lb. kapas per acre.	No manure yield, lb. kapas per acre.	Ratio $\frac{q}{p} = \frac{\text{cost per lb. nitrogen}}{\text{price per lb. seed cotton}}$				
		1	2	3	4	5
200	148	38	11	..	..	..
400	300	61	40	19	..	..
600	452	77	60	42	25	8
800	604	86	72	57	43	29
1000	756	94	82	69	57	44

Under the conditions of soil and climate under which the trials discussed in the present chapter were carried out, the above two tables should serve as schedules for the manuring of cotton with nitrogen. It would appear from table X that at current levels of cost of fertiliser and price of seed cotton, giving the ratio $\frac{q}{p}$ in the neighbourhood of 3 as stated earlier, manuring with 20 to 70 lb. per acre of nitrogen on land of medium to high fertility would be expected to give a most profitable return. Manuring of poor land would not be profitable. The verification of these schedules under cultivators' practice is desirable and would be of considerable interest in assessing the practical value of the method employed in the present investigation for analysing the results of manurial trials.

General Remarks.

For achieving self-sufficiency in our cotton production, increasing the yield per acre would be the means on which we must mainly rely, since extension of cotton acreage has a limited scope and with the existing low yields of crops, the problem of self-sufficiency in different agricultural commodities cannot obviously be solved by extension of cultivation alone. The series of manurial trials, whose results are described in the present chapter, confirm the earlier findings that in suitable areas, the yield of rainfed cotton can be increased by nitrogenous manuring and further demonstrate that substantial increases in yield, from one to three maunds per acre, can be realized profitably by employing ammonium sulphate or groundnut cake at prescribed rates of application. The condition essential for the successful use of nitrogenous fertilizers and manures on rainfed cotton, *viz.* adequacy of rainfall, exists in several parts of the peninsular India, as in Madhya Bharat, Berar and Nimar district of Madhya Pradesh, parts of Gujerat and East Khandesh district of Bombay Province, Nanded district of Hyderabad State and Tinnevelly area of Madras Province, and if fertilizer can be made available for cotton, the results of the present series of trials would provide guidance for its most efficient utilization on rainfed cotton.

The conclusions from the present trials however suffer to some extent from the limitation that these trials were carried out only at Government farms and it would be desirable to test the findings under the cultivators' conditions. The fact that the results have been related to soil fertility level is of considerable help in making practical recommendations and it is suggested that agricultural officers may base their recommendations to individual farmers in regard to the dose of nitrogen and other details of manuring on the data given in the present chapter and record their observations and results in the form of a suitable questionnaire drawn up for this purpose. Such observations will be very useful in assessing the effectiveness of the manure and its profitableness under actual growers' conditions. Secondly, extensive trials with a simple layout, in the manner recommended by Stewart (1947), may be carried out in selected districts. It is, however, suggested that doses of nitrogen to be employed, instead of being uniform over all the trials, may be fixed in accordance with the level of the initial productivity of the experimental field. The dressings, one in the neighbourhood of its optimum value as calculated from the general formula given here and another at half of the optimum value, may be included in the trial in addition to a no-manure control. The results of such a series of trials would provide valuable information for verifying the present conclusions.

REFERENCES.

(1) FISHER, R. A. .. .. .. (1946) Statistical Methods for Research Workers. Edinburgh, Oliver & Boyd., London, 10th Edition.

(2) STEWART, A. B. .. .. (1947) Report on Soil Fertility Investigations in India with special reference to Manuring. Indian Council of Agricultural Research, New Delhi.

(3) SUKHATME, P. V. .. .. (1941) Ind. Jour. Agric. Sci., 11, 325.

(4) YATES, F. .. .. .. (1935) Discussion on "Statistical Problems in Agricultural Experimentation" by J. Neyman, Suppl. Jour. Roy. Stat. Soc., 2, 107.

APPENDIX A.

List of Official publications used as sources of experimental data.

Bombay.

1. Annual Experimental Records of the Department of Agriculture in Bombay Presidency. Government Central Press, Bombay. Years 1933-34, 1934-35, 1935-36, 1936-37, 1937-38.

2. Experiments in Manuring Crops, Bombay Presidency, 1898-1931, D. L. Sahasrabudhe. Government Central Press, Bombay 1934.

C. P. and Berar.

1. Reports on Experimental Farms from the year ending 31st March 1931 to the year ending 31st March 1936.

2. A consolidated record of the field experimental works carried out by the Department of Agriculture in the Central Provinces and Berar between 1900 and 1930.
   R. G. Allan.
   Government Printing Press, Nagpur, 1933.

Madras.

1. Report on the work of the Agricultural Research Stations for the years 1905-06 to 1939-40.

Punjab.

1. A summary of the more important results arrived at or indicated by the Agricultural Stations and Research Officers in the Punjab during the years 1930-31 to 1934-35. Government Printing Press, Lahore, 1936.

2. A summary of the more important results arrived at or indicated by the Agricultural Stations and Research Officers in the Punjab during the years 1934-35 to 1937-38.
   Government Printing Press, Lahore, 1940.

United Provinces.

Triennial Report of the Experiments carried out on various Agricultural Stations during the years 1932-33, 1933-34 and 1934-35.
Government Printing Press, Allahabad, 1936.

Indore.

Progress Reports for the years 1936-37 to 1939-40, Institute of Plant Industry, Indore Central India.

I. C. A. R.

1. Analysis of Manurial Experiments in India.
   Imperial Council of Agricultural Research, Vol. I.
   M. Vaidyanathan, Government of India Press, Simla, 1934.

2. Analysis of Manurial Experiments in India.
   Imperial Council of Agricultural Research, Vol. II.
   M. Vaidyanathan, Government of India Press, Simla, 1933.

APPENDIX B.

RESULTS OF COTTON MANURIAL TRIALS IN INDIA*.

TABLE I.—BOMBAY PROVINCE.

Artificial Fertilizers.

Station.	Year 19-	Amount of artificials. lbs. per acre. N	P_2O_5	K_2O	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
Surat ..	08–14 16–21 17–22 32–37	10	..	..	39	11	
	28	15	..	..	8	34	
	**31	16	..	..	160	54	
	28 32–37	20	..	..	63	20	
	**34	20	..	..	120	35	
	**31	24	..	..	140	54	
	32–37	40	..	..	207	34	
	**34	..	20	..	–40	35	Over 20 lbs. N as Amm. Sulphate.
	**34	..	60	..	–80	35	
	**31	16	16	..	80	35	
	**34	20	20	..	80	85	
	**31	24	24	..	185	20	
	**34	20	60	..	40	35	
*Dabhoi*** ..	37	20	..	..	100	6	
	36	20	..	..	58	6	Average response in a NPK experiment. Basal dressing of 10-15 cartloads of F.Y.M.
	37	40	..	..	160	6	
	37	..	20	..	120	6	
	36	..	20	..	72	6	Do.
	37	..	20	..	100	6	Over 20 lbs. N as Am Sulphate.
	37	..	20	..	60	6	„ 40 „ „
	37	..	40	..	300	6	
	37	..	40	..	260	6	„ 20 „ „
	37	..	40	..	240	6	„ 40 „ „
	36	..	..	20	27	6	Average response in a NPK experiment, Basal dressing of 10–15 cartloads of F. Y. M.
	37	20	20	..	200	6	
	37	20	40	..	340	6	
	37	40	20	..	220	6	
	37	40	40	..	420	6	

Organic Manures.

Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre.	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
08–14	F. Y. M. 0.9 tons ..	10	–10	31	
34	„ 2.5 „	28	58		
32–37	„ 4.5 „	50	88	39	
08–14	„ 5.0 „ ..	56	76	41	
19,20,21	„ 5.0 „ ..	56	66	34	Unreplicated. Years as replicates.
„	„ 7.5 „	84	67	34	
„	„ 10.0 „	112	22	34	
22–28	„ 10.0 „	112	225	10	In trenches.
22–28	„ 10.0 „	112	157	9	Partly in trenches.
19,20,21	„ 12.5 „	140	10	34	Unreplicated. Years as replicates.
„	„ 15.0 „	168	–49	34	
„	„ 17.5 „	196	–29	34	
„	„ 20.0 „	224	–3	34	
„	„ 22.5 „	252	81	34	
„	„ 25.0 „	280	85	34	
08–11	Castor Cake .. .. (300 lbs. approx.)	20	20	18	
08–11	Crushed cotton seed .. (700 lbs. approx.)	20	17	21	
08–11	Crushed neem seed ..	20	–25	21	

**General Note.*—Unless otherwise mentioned in the remarks column, the responses are over No Manure.

**At stations marked thus, experiments were carried out by Imperial Chemical Industries (India)Ltd.

TABLE I—BOMBAY PROVINCE—(*contd.*)

Artificial Fertilizers. *Organic Manures.*

Station.	Year 19-	Amount of artificials.			Response. (Difference from control) lbs. of seed cotton per acre	S. E. of response	REMARKS.	Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre.	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
		lbs. per acre. N	P_2O_5	K_2O									
Broach ..	32–36	10	..	..	57	10	Over Sann buried between two rows of cotton in August.	19,20, 21,22	F.Y.M. 7.5 tons ..	84	129	104	
Jalgaon ..	29, 30, 32	6	..	..	30	36	Over 100 lbs. of Castor Cake.	,,	Castor Cake (400 lbs. approx.) ..	24	13	104	Unreplicated.
	,,	10	..	..	63	39							
	24, 25, 26	16	..	..	19	15	Over 7.5 tons F. Y. M. (84 lbs. N).	,,	Night soil. .. .. 30 carts.	252	234	104	Years as replicates.
	29, 30, 32	20	..	..	124	21							
	,,	20	..	..	116	37	Over 100 lbs. of Castor Cake.						
	24, 25, 26	24	..	..	48	15	Over 7.5 tons F. Y. M. (84 lbs. N).						
	29, 30, 32	20	20	..	70	39							
Dhulia ..	12	10	..	..	-140	14		06	F. Y. M. 7.5 tons.	84	168	..	Unreplicated.
	12	20	..	..	-70	14		07	,, 10.0 ,,	112	84	..	Do.
	06	22	..	..	-26	..	Unreplicated.						
Dharwar ..	08–16	10	..	..	54	12		08–16	,, 0.9 ,,	10	61	15	
	08–14	20	..	..	1	24	Unreplicated. Years as replicates.	28	,, 1.8 ,,	14	5	46	Over 28 lbs. N. Sodi. Nitrate, Basal dressing of 2.5 tons. F.Y.M.
	24–27	20	..	..	0	84	Do.						
	33–36	28	..	..	56	..							
	28	28	..	..	10	37	Over 2.5 tons F.Y.M.	29	,, 2.5 ,,	28	-45	46	Do.
	29	28	..	..	202	38	After manuring Jowar with 2.5 tons F. Y. M. and 14 lbs. N. Sodium Nitrate. Basal dressing 2.5 tons of F.Y.M.						After manuring Jowar, Basal dressing of 2.5 tons F. Y. M.
	08–14	..	19	..	27	24	Unreplicated. Years as replicates.	12–15	,, 5.0 ,,	56	145	56	Unreplicated. Years as replicates.
	24–27	..	21	..	-5	84	Over 20 lbs. N as Am. Sulphate.	24–27	Safflower cake (850 lbs. approx.) ..	28	95	84	
	28	..	31	..	-45	37	,, 28 ,, ,,	28	Do. ..	28	-55	46	Basal dressing of 2.5 tons F.Y.M.
	32–37	4	26	..	-38	..	Bonemeal.						
	32–37	8	52	..	-14	..	Bonemeal.	28	Do. ..	28	110	46	Basal dressing of 2.5 tons F. Y. M. After manuring Jowar.
	08–14	..	..	48	-17	24	Unreplicated. Years as replicates.						
	12–13	..	..	43	65	35	Over 1.5 tons F. Y. M.+ 224 lbs. Super +60 lbs. Am. Sulphate.	12–15	Cotton waste, 5 tons. ..	168	90	56	
Arbhavi ..	29–30	28	..	..	-100	88							
	,,	28	..	..	120	46	Basal dressing of 2.5 tons F.Y.M.						
	,,	..	31	..	-112	88	Over 28 lbs. N.						
	,,	..	31	..	-84	46	Over 28 lbs. N. Basal dressing of 2.5 tons F. Y. M.						

TABLE II.

C. P. AND BERAR.

Artificial Fertilizers.

Station.	Year 19-	Amount of artificials. lbs. per acre. N	P_2O_5	K_2O	Respones. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
Akola ..	30–34 31–35 30–32 31 37–39	20	..	..	105	15	
	9–21 28–30	20	..	..	90	..	
	37–39 37–38 39	20	..	..	61	17	Over basal dose of 20 lbs. N. F. Y. M.
	„	20	..	..	50	17	Do. + 45 lbs. P_2O_5.
	„	20	..	..	38	17	Do. + 60 lbs. K_2O.
	„	20	..	..	53	17	Do. + 45 lbs. P_2O_5 + 60 lbs. K_2O.
	9–21	20	..	..	149	..	Over 40 lbs. P_2O_5.
	9–21 10–20	20	..	..	113	..	Over 35 lbs. K_2O.
	10–20	20	..	..	132	..	Over 50 lbs. P_2O_5.
	9–21 10–20	20	..	..	174	..	Over 50 lbs. P_2O_5. +35 lbs. K_2O.
	30–34 31–33	30	..	..	148	24	
	9–21	30	..	..	235	..	
	37–39 39	40	..	..	191	14	
	33–35 34 36–38 37–39	40	..	..	16	19	Over 20 lbs. N—Cattle dung.

Organic Manures.

Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre.	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response.	REMARKS.
	Groundnut cake.				
36–38 37–39	200 lbs. ..	15	95	16	
30–34 31–35	240 „ ..	19	81	10	
30–34 31–35 36–38 37–39	320 „ ..	25	114	9	
30–34 31–35 36–38, 37–39,	400 „ ..	32	172	11	
36–38, 37–39.	440 „ ..	35	140	14	
30–34, 31–35	480 „ ..	38	148	14	
	Castor cake.				
26–28	240 lbs. ..	16	65	..	
28–30	320 „ ..	21	–8	..	
08–20	400 „ ..	26	310	..	
22–29	480 „ ..	31	81	..	
08–20	560 „ ..	36	337	..	
„	720 „ ..	47	251	..	
22–29	800 „ ..	52	80	..	
	Cattle dung.				
30–34, 31–35, 30–32, 31	1.8 ton.	20	68	20	
28–30	1.8 „ ..	20	80	..	
9–16	2.3 „ ..	26	90	..	
33–35, 34,36–38 37-39, 39	3.6 „ ..	40	91	16	

TABLE II.—C. P. AND BERAR—(*contd.*)

Artificial Fertilizers.

Station.	Year 19-	Amount of artificials. lbs. per acre.			Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
		N	: P_2O_5 :	K_2O			
Akola .. (contd.)	30-34(2) 31-35(2)	..	15	..	44	16	Over 19 lbs. N—groundnut cake.
	30–34 31–35 30–32 31	..	15	..	—13	20	Over 20 lbs. N—cattle dung.
	,,	..	15	..	22	20	Over 20 lbs. N as Am. sulphate.
	28–30	..	15	..	—31	..	Do.
	,,	..	15	..	42	..	Over 20 lbs. N—cattle dung.
	26–30	..	15	..	55	..	Over 16 lbs. N Castor cake
	10–20	..	20	..	116	..	,, 20 ,, Am. sulphate.
	30-34(2) 31-35(2)	..	22	..	38	16	,, 19 ,, Groundnut cake.
	26–30	..	25	..	45	..	,, 16 ,, Castor cake.
	30-34(2) 31–35(2)	..	30	..	35	16	,, 19 ,, Groundnut cake.
	26–30	..	30	..	0	..	,, 16 ,, Castor cake.
	9–21	..	40	..	120	..	
	,,	..	40	..	74	..	,, 20 ,, +35lbs.K_2O.
	,,	..	40	..	173	..	,, 20 ,, (Av. of Am. sulphate and Sodi. Nitrate.)
	37–39 37–38 39	..	45	..	36	17	Over basal dose of 20 lbs. N.F.Y.M.
	,,	..	45	..	25	17	Do. + 20 lbs. N.
	,,	..	45	..	15	17	Do. +20 lbs. N+60 lbs. K_2O
	10–20	..	50	..	97	..	
	,,	..	50	..	152	..	Over 20 lbs. N. (Av. of Am. sulphate and Sodi. Nitrate.)
	,,	..	50	..	121	..	Over 20 lbs. N+35 lbs. K_2O
	9–21 10–20	..	..	35	19	..	
	,,	..	..	35	51	..	Over 20 lbs. N (Av. of Am. sulphate and Sodi. Nitrate.)

Organic Manures.

Year 19-	Amount of manures per acre.	Equivalent amount of N, P, K, lbs. per acre.			Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
		N	: P_2O_5 :	K_2O			
	Mixture of Artificial and Organic Manure.						
	Am. sulphate + Ground nut cake.						
36–38 37–39	5 N+10 N ..	15	..	..	78	14	
,,	8 N+17N ..	25	..	..	136	14	
,,	12 N+23N ..	35	..	..	199	14	
	Am. sulphate+Cattle dung.						
33–35 34, 36–38 37–39, 39	20 N+20 N ..	40	..	..	82	16	
	Sodi. Nitrate + Cattle dung.						
08–16	20 N+13N ..	33	..	..	279	..	
,,	10 N+26 N ..	36	..	..	360	..	
	Superphosphate + Groundnut cake.						
30–34 31–35	80 lbs. + 240 lbs	19	15	..	121	16	
,,	120 ,, + 240 ,,	19	23	..	116	16	
,,	160 ,, + 240 ,,	19	30	..	113	16	
	Superphosphate + Cattle dung.						
30–34 31–35 30–32 31	80 lbs. + 1.8 tons	20	15	..	65	20	
28–30	80 ,, + 1.8 ,,	20	15	..	122	..	
	Superphosphate + Castor cake.						
26–28	80 lbs. +240 lbs.	16	15	..	120	..	
,,	120 ,, + ,, ,,	16	23	..	110	..	
,,	160 ,, + ,, ,,	16	30	..	65	..	
	Pot. Nitrate+Cattle dung.						
08–16	20 N+1.2 tons. ..	33	..	54	266	..	
,,	10 N+2.4 ,, ..	36	..	27	245	..	

TABLE II.—C. P. AND BERAR—(*contd.*)

Artificial Fertilizers. *Organic Manures.*

Station.	Year 19-	Amount of artificials. lbs. per acre. N	P₂O₅	K₂O	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.	Year 19-	Amount of manures per acre.	Equivalent amount of N, P, K, lbs. per acre. N:P₂O₅:K₂O	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
Akola .. (contd.)	9–21	..	..	35	–29	..	Over 20 lbs. N + 40 lbs. P_2O_5.						
	10–20	..	..	35	–10	..	„ + 50 lbs. P_2O_5.	28–30	Super + Potash + Cattle dung. 80 lbs. + 80 lbs. + 1.8 tons.	20 15 38	102		
	30–34 31–35 30–32 31	..	..	38	14	20	Over 20 lbs. N + 15 lbs. P_2O_5.						
	28–30	..	..	38	–35	..	„ 16 „ + „						
	37–39 37–38 39	..	..	60	27	17	Over basal dose of 20 lbs. N, F. Y. M.						
	37–39 37–38 39	..	..	60	5	17	Over basal dose of 20 lbs. N, F.Y.M. + 20 lbs. N as Am. sulphate.						
	„	..	..	60	–9	17	„ + 45 lbs. P_2O_5 as Superphosphate.						
	„	..	..	60	–6	17	„ + 20 lbs. N. + 45 lbs. P_2O_5.						
	30–34 31–33	9	9	..	60	19							
	28–30	16	15	..	105	..							
	30–34 31–33	18	18	..	88	19							
	30–34 31–35 30–32 31	20	15	..	115	20							
	28–30	20	15	..	69	..							
	9–21	20	40	..	269	..							
		20	40	..	187	..	Over 35 lbs. K_2O.						
	37–39 37–38 39	20	45	..	86	17	Over basal dose of 20 lbs. N, F.Y.M.						
	10–20	20	50	..	229	..							
	30–34 31–33	30	30	..	150	24							
	9–21	30	30	..	222	..							
	30–34 31–33	30	90	..	155	24							
	„	36	36	..	163	19							
	„	54	54	..	216	19							
	9–21 10–20	20	..	35	132	..							

TABLE II—C. P. AND BERAR—(*contd.*)

Artificial Fertilizers. *Organic Manures.*

Station.	Year 19-	Amount of artificials. lbs. per acre. N	P_2O_5	K_2O	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.	Year 19-	Amount of manures per acre.	Equivalent amount of N, P, K. lbs. per acre $N:P_2O_5:K_2O$	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response.	REMARKS.
Akola .. (contd.)	10-20	20	..	35	122	..	Over 50 lbs. P_2O_5 as Superphosphate.						
	9-21	20	..	35	120	..	„ 40 „ „ Superphosphate						
	37-39 37-38 39	20	..	60	65	17	Over basal dose of 20 lbs. N, F.Y.M.						
	„	20	..	60	44	17	Do. +45 lbs. P_2O_5.						
	28-30	..	15	38	22	..	Over 20 lbs. N, Cattle dung						
	9-21	..	40	35	102	..							
	„	..	40	35	7	..	Over 20 lbs. N (Av. of Am. sulphate and Sodi. Nitrate).						
	37-39 37-38 39	..	45	60	27	17	Over basal dose of 20 lbs. N, F.Y.M.						
	„	..	45	60	19	17	Do. +20 Lbs. N, Am. sulph.						
	10-20	..	50	35	9	..							
	„	..	50	35	154	..	Over 20 lbs. N.						
	28-30	16	15	38	70	..							
	30-34 31-35 30-32 31	20	15	38	128	20							
	9-21	20	40	35	240	..							
	37-39 37-38 39	20	45	60	80	17	Over basal dose of 20 lbs. N, F. Y. M.						
	10-20	20	50	45	219	..							
	30-34 31-33	30	30	60	145	24							
	9-21	30	30	60	226	..							
Buldhana ..	29	20	..	..	62	..							
	37, 38, 39	20	..	..	74	36	Basal dose of 20 lbs. N, F.Y.M.	29	Groundnut cake. 240 lbs.	19	27	..	
	„	20	..	..	38	36	Do. +45 lbs. P_2O_5	29	Groundnut cake + Am. sulphate. 120 lbs. + 50 lbs.	19	—77	..	
	„	20	..	..	25	36	Do. + 60 lbs. K_2O						
	„	20	..	..	27	36	Do. +45 lbs. P_2O_5 +60 lbs. K_2O.						

TABLE II.—C. P. AND BERAR—(*contd.*)

Artificial Fertilizers. *Organic Manures.*

Station.	Year 19-	Amount of artificials. lbs. per acre.			Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.	Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre.	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
		N	P_2O_5	K_2O									
Buldhana (contd.)	37, 38, 39	..	45	..	54	36	Basal dose of 20 lbs. N. F.Y.M.						
	,,	..	45	..	18	36	Do. +20 lbs. N.						
	,,	..	45	..	44	36	Do. +60 lbs. K_2O.						
	,,	..	45	..	46	36	Do. +20 lbs. N+60 lbs. K_2O						
	,,	..	..	60	26	36	Basal dose of 20 lbs. N, F.Y.M.						
	,,	..	..	60	-23	36	Do. +20 lbs. N.						
	,,	..	..	60	16	36	Do. +45 lbs. P_2O_5.						
	,,	..	..	60	5	36	Do. +20 lbs. N +45 lbs. P_2O_5.						
	,,	20	45	..	92	36	Basal dose of 20 lbs. N, F.Y.M.						
	,,	20	45	..	71	36	Do. +60 lbs. K_2O.						
	,,	20	..	60	51	36	Basal dose of 20 lbs. N, F.Y.M.						
	,,	20	..	60	43	36	Do. +45 lbs. P_2O_5.						
	,,	..	45	60	70	36	Basal dose of 20 lbs. N, F.Y.M.						
	,,	..	45	60	23	36	Do. +20 lbs. N.						
	,,	20	45	60	97	36	Basal dose of 20 lbs. N, F.Y.M.						
Yeotmal ..	21–27 26–29	20	..	..	100	..		29	Groundnut cake. 240 lbs.	19	82	..	
	21–29	20	..	..	111	..	Basal dose of Cattle dung.	29	Do. ..	19	160	..	Basal dose of Cattle dung
								29	Groundnut cake + Am. sulphate. 120 lbs. + 50 lbs.	19	90	..	
								29	Do.	19	189	..	Do.
Borgaon ..	29	20	..	..	5	..	Basal dose of Cattle dung.	29	Groundnut cake. 240 lbs.	19	115	..	
	29	20	..	..	-18			29	,, ...	19	80	..	Basal dose of Cattle dung.
								29	Groundnut cake + Am. sulphate. 120 lbs. + 50 lbs. ..	19	83	..	
								29	,, ..	19	85	..	Do.
Basim ..	29	20	..	..	60	..		29	Groundnut cake 240 lbs.	19	116	..	
								29	Groundnut cake + Am. sulphate. 240 lbs. + 50 lbs.	19	94	..	

TABLE II.—C. P. AND BERAR—(*contd.*)

Artificial Fertilizers. *Organic Manures.*

Station.	Year 19-	Amount of artificials. lbs. per acre. N	P_2O_5	K_2O	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.	Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre.	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
Nagpur ..	27-29 27	16	..	..	99	..		32-34	Groundnut cake. 320 lbs.	26	143	76	
	31-33(2) 32-34	16	..	..	48	29							
	31-33 32-34	20	..	..	51	31							
	06-20 27-29	20	..	..	122								
	30-32 31-33(3) 32-34	30	..	..	88	20							
	26-29	30	..	..	109	..							
	6-20	..	50	..	38	..	Over 20 lbs. N+35 lbs. K_2O.						
	6-20	..	..	35	72	..	Over 20 lbs. N, as average of Sodi. Nitrate + Am. sulphate.						
	30-32 31-33	..	..	115	5	25	Over 30 N+30P (Nicifos).						
	30-32 31-33	9	9	..	48	26	Nicifos 22/18.						
	,,	18	18	..	54	26	Do.						
	6-20	20	50	..	245	..	Sodi Nitrate+Super.						
	30-32 31-33	30	30	..	96	25	Nicifos 22/18.						
	,,	30	88	..	96	25	,, 17/41.						
	,,	36	36	..	138	26	,, 22/18.						
	,,	54	54	..	159	26	,, ,,						
	0-20	20	..	35	249	..	Sodi Nitrate+Potash.						
	30-32 31-33	...	30	115	-24	24	Over 30 lbs. N, as Am. sulph.						
	6-20	..	50	35	110	..	Over 20lbs. N,asAv. of Sodi Nitrate+Am. sulphate.						
	30-32 31-33	30	30	115	101	25	Nicifos 22/18 + Potash sulphate.						
	6-20	20	50	35	287	..							

TABLE II.—C. P. AND BERAR—(*contd.*)

Artificial Fertilizers. *Organic Manures.*

Station.	Year 19-	Amount of artificials. lbs. per acre.			Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.	Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS
		N	P_2O_5	K_2O									
Khandwa	37(2) 38(2) 39	20	..	..	64	45	Basal dose of 20 lbs. N, F.Y.M.						
	,,	20	..	..	73	45	Do. +45 lbs. P_2O_5.						
	,,	20	..	..	82	45	Do. +60 lbs. K_2O.						
	,,	20	..	..	97	45	Do. +45 lbs. P_2O_5 + 60 lbs. K_2O.						
	**30	30	..	..	215	52							
	31, 32	30	..	..	77	11							
	**30	..	30	..	−15	52	Over 30 lbs. N.						
	37(2) 38(2) 39	..	45	..	8	45	Basal dose of 20 lbs. N, F.Y.M.						
	37(2) 38(2), 39	..	45	..	7	45	Basal dose of 20 lbs. N, F.Y.M. + 20 lbs. N.						
	,,	..	45	..	−18	45	Do. +60 lbs. K_2O.						
	,,	..	45	..	−3	45	Do. +20 lbs. N + 60 lbs. K_2O.						
	**30	..	96	..	−11	60	Over 30 lbs. N.						
	37(2) 38(2) 39	..	..	60	20	45	Basal dose of 20 lbs. N, F.Y.M.						
	,,	..	..	60	38	45	Do. + 20 lbs. N.						
	,,	..	..	60	−6	45	Do. + 45 lbs. P_2O_5.						
	,,	..	..	60	18	45	Do. + 20 lbs. N + 45 lbs. P_2O_5.						
	**30	..	..	120	8	60	Over 30 lbs. N + 30 lbs. P_2O_5 in Nicifos 22/18.						
	31, 32	9	9	..	−35	38	Nicifos 22/18						
	**30	9	9	..	34	61	Do.						
	31, 32	18	18	..	−15	38	Do.						
	**30	18	18	..	203	61	Do.						
	37(2), 38(2), 39	20	45	..	81	45	Basal dose of 20 lbs. N, F.Y.M.						
	,,	20	45	..	79	45	Do. + 60 lbs. K_2O.						
	**30	30	30	..	200	60	Nicifos 22/18.						
	31, 32	30	30	..	42	20	Do.						
	,,	30	88	..	85	20	,, 17/41						
	**30	30	96	..	204	60	,, ,,						

**Carried out by Imperial Chemical Industries (India), Ltd.

TABLE II.—C. P. AND BERAR—(*contd.*)

Artificial Fertilizers. | *Organic Manures.*

Station.	Year 19-	Amount of artificials. lbs. per acre.			Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.	Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre.	Response. (Difference from control lbs. of seed cotton per acre.	S. E. of response	REMARKS.
		N	P_2O_5	K_2O									
Khandwa . .	31, 32	36	36	. .	111	38	Nicifos 22/18						
	**30	36	36	. .	266	61	,, ,,						
	31, 32	54	54	. .	158	38	,, ,,						
	**30	54	54	. .	327	61	,, ,,						
	37(2), 38(2), 39	20	. .	60	102	45	Basal dose of 20 lbs. N, F.Y.M.						
	,,	20	. .	60	81	45	Do. + 45 lbs. P_2O_5.						
	37(2), 38(2), 39	. .	45	60	2	45	Basal dose of 20 lbs. N, F.Y.M.						
	,,	. .	45	60	35	45	Do. + 20 lbs. N, F.Y.M.						
	,,	20	45	60	99	45	Basal dose of 20 lbs. N, F.Y.M.						
	31, 32	30	30	58	17	20							
	**30	30	30	120	208	61							
Powarkhera (Hoshangabad).	30–34 31–33	20	. .	. .	81	24		08–16	F. Y. M. 1.8 tons . .	20	55	. .	
								,,	,, 3.6 ,, . .	40	102	. .	
	8–16 26–29	20	. .	. .	160	. .							
Chhindwara	26–29	20	. .	. .	28	. .							
Chandkheri	,,	20	. .	. .	7	. .	Over 10 tons Cattle dung.		Cattle dung 10 tons . .	40	120	. .	
	,,	. .	15	. .	50	. .	Do.		Castor cake	40	40	. .	
	,,	. .	15	. .	2	. .	Over 800 lbs. Tilli cake.						
	,,	. .	30	. .	26	. .	Over 10 tons Cattle dung.						
	,,	. .	30	. .	–63	. .	Over 800 lbs. Tilli cake.						
	,,	. .	38	. .	–30	. .	Over 10 tons Cattle dung.						
	,,	. .	38	. .	30	. .	Over 800 lbs. Tilli cake.						

**Carried out by Imperial Chemical Industries (India), Ltd.

TABLE III

INDORE

Artificial Fertilizers.

Station	Year 19-	Amount of artificials. lbs. per acre. N	P₂O₅	K₂O	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS	
Indore ..	37(3) 38(3)	10	..	..	48	14	More-fertile fields (471).*	
	37(2) 38(3)	10	..	..	4	16	Poor fields (209).	
	36, 37(2), 39	20	..	..	70	29	More fertile fields (457)	
	39	20	..	..	16	23	Poor fields (274).	
	37(5), 38(6) 39(8)	25	..	..	91	12	More fertile fields (396).	
	37(2), 38(6), 39	25	..	..	71	82	Poor fields (158).	
	39	40	..	..	192	51	More fertile fields (390),	
	39	40	..	..	–3	23	Poor fields (274).	
	37(2), 38(3)	50	..	..	102	19	More fertile fields (385),	
	38(4)	50	..	..	94	62	Poor fields (142).	
	37(5), 38(6)	..	10	..	3	11		
	36, 37(2)	..	18	..	62	26		
	39(2)	..	21	..	–19	17		
	37(5), 38(7), 39(5)	..	25	..	–1	24		
	38, 39	..	50	..	–37	122		
	37(5), 38(4)	..	..	10	7	10		
	38(4)	..	..	23	2	10		
	38(2)	10	10	..	–38	18	More fertile fields (472)	Average response in a NPK expt.
	38(2)	10	10	..	34	26	Poor fields (222)	
	,,	10	25	..	–30	18	More fertile fields (472)	
	,,	10	25	..	5	26	Poor fields (222)	
	36, 37(2)	18	18	..	102	26	More fertile fields (488)	Nicifos 22/18.
	38(3), 39(8)	25	25	..	112	18	More fertile fields (392)	Do.
	38(3) 39(3)	25	25	..	70	42	Poor fields (184)	Do.
	38(2)	25	10	..	72	18	More fertile fields (472)	Average response in a NPK expt.
	38(2)	25	10	..	24	26	Poor fields (222)	

Organic Manures.

Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre.	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response.	REMARKS.
	Compost.				
37(2)		15	–25	42	More fertile fields (623).
36		18	67	10	Do. (848).
37(2) 38, (3)		25	43	19	Do. (385).
38(3)		25	16	18	Poor fields (149).
37(2), 38 (3)		50	64	19	More fertile fields (385).
38(3)		50	2	18	Poor fields (149).
	Groundnut cake.				
38, 39(3)		25	93	31	More fertile fields (410).
38, 39(2)		25	68	19	Poor fields (202).
38		50	196	55	More fertile fields (452).
38		50	77	35	Poor fields (178).
	Linseed cake.				
38		25	175	55	More fertile fields (452).
38		25	11	35	Poor field (178)
38		50	158	55	More fertile fields (452).
38		50	5	35	Poor fields (178).
	Tilli cake.				
38		25	25	35	More fertile fields (452).
38		25	11	35	Poor fields (178).
38		50	82	55	More fertile fields (452).
38		50	12	35	Poor fields (178).
	Karanj cake.				
38		25	93	55	More fertile fields (452).
38		25	112	35	Poor fields (178).
38		50	82	55	More fertile fields (452).
38		50	45	35	Poor fields (178.)
	Safflowercake.				
36		18	90	31	More fertile fields (348).
37(2)		51	2	42	Do. (348)
	Am. sulphate + Compost. 12.5 lbs. N each.				
38(2)		25	54	28	More fertile fields (416)
,,		25	30	20	Poor fields (134).
,,	Do. 25 lbs. N each.	50	43	28	More fertile fields (416).
,,		50	8	20	Poor fields (134).

TABLE III.—INDORE—(*contd.*)

	Artificial Fertilizers.								*Organic Manures.*					
Station	Year 19-	Amount of artificials. lbs. per acre. N	P_2O_5	K_2O	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.		Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre.	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
Indore .. (contd.)	38	25	73	..	55	55	More fertlile fields (452)	Nicifos 17/41						
	38	25	73	..	68	35	Poor fields (178)							
	38	50	50	..	20	55	More fertile fields (452)	Nicifos 22/18						
	38, 39	50	50	..	130	122	Poor fields (150)							
	38	50	146	..	283	55	More fertile fields (452)	Nicifos 17/41						
	38	50	146	..	25	35	Poor fields (178)							

Note :—Figures in brackets are for the average yield in lbs. per acre for untreated plots and are included to show the fertility differences of the fields.

TABLE IV

MADRAS PROVINCE

Artificial Fertilisers. *Organic Manures.*

Station	Year 19-	Amount of artificials. lbs. per acre.			Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.	Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre.	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
		N	: P₂O₅	: K₂O									
Hagari ..	24	15	..	..	–3	4		14–23	Cattle manure 4.5 tons yearly.	50	58	4	Unreplicated. Years as replicates.
	21, 22, 23	20	..	..	6	17							
	27	20	..	..	33	..	Unreplicated.						
	27	..	20	..	56	..	Do.	14–23	Cattle manure 4.5 tons alternate year.	50	13	4	Do.
	31, 32, 33	45	20	..	24	11							
Bellary ..	05–08	..	36	..	–49	17		05–08 05-08	Safflower Cake 1000 lbs.	58	–55	23	
	05–08	..	57	..	12	43							
	05–08	..	57	..	–72	43	Over 1,000 lbs. Safflower. Cake.						
								05–08	Do.	58	–107	43	Over 800 lbs. of Superphosphate (57 lbs. P.).
	05–08	38	..	51	–22	17							
	05–08	42	..	114	–122	43							
	05–08	28	51	76	–127	43							
Nandyal	23–24	15	..	..	0	7		19, 21	Poudrette (1,600 lbs.)	13	–3	..	Unreplicated.
	22, 23, 24	20	..	..	–7	7							
	24	20	..	..	26	..	Unreplicated.	32, 33	Cattle manure 2.5 tons	28	9	14	
	31	22	20	..	–16	11							
	31	45	20	..	–23	4		12–23	,, 5.0 ,, yearly.	56	108	..	Do.
	32–33	45	20	..	50	14							
								12–23	Do. alternate years.	56	88	..	Do.
								21	Cattle manure, 10.0 tons.	112	0	..	Do.
Guntur ..	32, 33	45	20	..	97	14	Over Cattle Manure 2.5 tons.						
Coimbatore	** 37	15	..	..	57	86	Av. response in a (3 × 3) factorial experiment.	26, 29	Cattle manure, continuous from 1909, 5.0 tons.	56	393	98	New permanent manurial trial.
	31, 32, 33	20	..	..	8	66				56	482	..	Old ,, ,, unreplicated.
	26–29	22	..	..	97	69	New permanent manurial trial.						
	26–29	22	..	..	63	..	Old ,, ,, unreplicated.	26, 29	Cattle manure upto 1916 and residual thereafter, 5.0 tons	56	184	98	New permanent manurial trial.
	** 37	30	..	..	118	86	Av. response in a (3 × 3) factorial experiment			56	69	..	Old ,, ,, unreplicated.
	32	34	..	..	80	63							
	31, 32, 33	60	..	..	3	66							
	29, 30, 31	60	..	..	–11	24	Field 5.	29	Cattle manure 7.5 tons		210	..	
	,,	60	..	..	123	36	,, 3.						
	31, 32, 33	80	..	..	–41	66				84	330	..	On 10 days irrigation.
	** 37	..	15	..	–44	86	Av. response in a (3 × 3) factorial experiment.						
											91	..	On 20 days irrigation.
	** 37	..	30	..	–36	86	Do.						
	26, 29	..	60	..	–17	69	New permanent manurial trial.						
	,,	..	60	..	148	..	Old ,, ,, unreplicated.						

TABLE IV.—MADRAS PROVINCE—(*contd.*)

Artificial Fertilisers

Organic Manures.

Station	Year 19-	Amount of artificials. lbs. per acre.			Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.	Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre.	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response.	REMARKS.
		N	P_2O_5	K_2O									
Coimbatore (contd.)	26, 29	....			272 22	..	In presence of N.) In absence of N.)						
	29, 30, 31	..	80	..	−12	17	Field 5.						
	,,	..	80	..	72	26	,, 3.						
	,,	..	..	40	26	17	,, 5.						
	,,	..	..	40	10	26	,, 3.						
	26, 29	..	..	52	−30	69	New permanent manurial trial.						
	,,	..	..	52	19	..	Old ,, ,, unreplicated.						
	29, 30, 31	45	20	..	8	26	* Dry red soil. Over 4.0 tons cattle manure.						
	,,	45	20	..	21	10	* Dry black soil. Over 4.5 tons cattle manure.						
Koilpatti	21, 22, 23	11	..	..	52	..		05–09	Neem cake, 1,000 lbs.	55	243	31	
								05	,, ,, ..	55	83	46	Over 300 lbs. of Superphosphate.
	31, 32, 33	22	..	..	73	30	On a basal dose of Cattle Manure = 6 cartloads + 112 lbs. of Am. sulphate + 112 lbs. Superphosphate.	06–07	,, ,, ..	55	420	..	
								06–07	,, ,, ..	55	312	..	
								31, 32, 33	Groundnut cake ..	20	123	30	Over" 112" lbs. "of" Am. sulphate and 112 lbs. Superphosphate.
	33	22	..	..	118	71	On a basal dose of Cattle Manure = 6 cartloads + 250 lbs. Am. sulphate + 112 lbs. of Superphosphate.		*Mixtures of Organic and Artificials.*				
								29, 31	Groundnut cake + Superphosphate.	(40N +20P)	220	32	
	32, 33, 34	45	..	..	125	20		30	,, ,, ..	(40N + 20P)	−8	22	Over basal dose of 6 cartloads of Cattle manure + 2 cartloads of cotton compost.
					142	20	In single dose.						
					128	20	In two doses.						
					110	28	In three doses.						
	05	..	57	..	180	46		32, 33	,, ,, ..	(40N + 20P)	106	42	Over basal dose of Cattle-manure = 6 cartloads.
	06, 07	..	57	..	107	..							
	05	..	57	..	30	46	Over 1,000 lbs. Neem cake.	33	,, ,, ..	(20N + 20P)	59	71	,, ,,
	06, 07	..	57	..	0	..	Do.						
	31, 32, 33	22	20	..	108	30	On a basal dose of 6 cartloads of Cattle manure.	31, 32, 33	Groundnut cake + Am. sulphate + Super phosphate.	(42N + 20P)	192	30	,, ,,
	29, 31	45	20	..	245	32		,,	Groundnut cake + Am. sulphate + Superphosphate.	(82N + 20P)	119	30	,, ,,

All experiments on irrigated Cambodia except two marked (*) in 1929, 30, and 31, which were on unirrigated Karunganni.

Experiments marked (**) were carried out by the Imperial Chemical Industries (India), Ltd.

TABLE IV.—MADRAS PROVINCE—(*contd.*)

Artificial Fertilisers. *Organic Manures.*

Station	Year 19-	Amount of artificials. lbs. per acre. N	P_2O_5	K_2O	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.	Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre.	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
Koilpatti	29	45	20	..	–10	84	@@ Red Soil. On a basal dose of 10 cartloads of Prickly Pear compost.						
	30	45	20	..	10	22	On a basal dose of 4 cartloads of Cattle Manure + 2 cartloads of cotton compost.						
	31, 32, 33	45	20	..	23	28	@@ Red Soil.						
	30	45	20	..	57	57	@@ Red Soil. On a basal dose of 10 cartloads of Prickly Pear Compost.						
	05	28	..	76	28	46	Over 300 lbs. of Superphosphate.						
	06, 07	28	..	76	182	..							
	05, 06, 07	42	..	114	187	..	Continuous cotton.						
	05	28	57	76	208	46							
	06, 07	28	57	76	289	..							
	05	28	51	76	134	46							
	06, 07	28	51	76	312								
	05–09	42	38	114	342	42							
	37	5	12	8	49	..	Parry's Fertilizer 112 lbs.						
	37	10	24	16	164	..	„ 224 „						
	37	20	48	32	233	..	„ 448 „						

@@ These experiments were carried out on irrigated Cambodia.

TABLE V

UNITED PROVINCES

Artificial Fertilisers.

Station	Year 19-	Amount of artificials. lbs. per acre. N	P₂O₅	K₂O	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
Raya	33	10	..	..	19	58	
	39	15	..	..	76	37	Desi (Cwn. 520)
	39	15	..	..	58	37	American (Perso-American)
	32, 33, 34 33 33	20	..	..	91	27	
	39	30	..	..	228	37	Desi (Cwn. 520)
	39	30	..	..	59	37	American (Perso-American)
	33	30	..	..	105	58	
	33	40	..	..	178	58	
	39	45	..	..	286	37	Desi (Cwn. 520)
	39	45	..	..	114	37	American (Perso-American)
	39	..	15	..	−9	32	Desi (Cwn. 520)
	39	..	15	..	21	32	American (Perso-American)
	39	..	30	..	−21	32	Desi (Cwn. 520)
	39	..	30	..	50	32	American (Perso-American)
	33	..	P*	..	87	58	Over 10 lbs. in Am. Sulphate.
	33	..	P	..	10	35	,, 20 ,, ,,
	33	..	P	..	−10	58	,, 30 ,, ,,
	33	..	P	..	43	58	,, 40 ,, ,,
	32, 33, 34	..	..	54	199	64	,, 20 ,, ,,
Cawnpore	06–14	20	..	..	48	..	
	26–29	24	..	..	−3	..	
	06–14	..	50	..	−53	..	

Organic Manures.

Station	Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre.	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
Raya	33, 34	Compost 4.0 tons.	45	−23	39	
	33, 34	F. Y. M. 4.0.. tons.	5	82	39	
	32, 33, 34	Castor Cake (300 lbs. approx.) ..	20	54	64	
Cawnpore	06–14	F. Y. M. 1.8 tons approx. ..	20	114	..	Over 50 lbs. P in Superphosphate.
	,,	F.Y. M. 4.4 ,, approx. ..	50	152	..	,, ,, ,,

*Phosphate in Nicifos—grades not known.

TABLE VI

PUNJAB

Artificial Fertilizers.

Station.	Year 19-	Amount of artificials. lbs. per acre. N	P₂O₅	K₂O	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
Lyallpur	25–28 33	12	..	..	25	58	
	33	12	..	..	10	54	Over green manure.
	25, 26, 27(7) 28(8), 29(2) 30(2), 31(3) 32(2) 33, 34, 35.	16	..	..	72	19	
	25–28(2) 27 31	20	..	..	189	30	
	32, 33, 34	20	..	..	47	33	Over green manure.
	25, 26, 27, (7) 28(8)	24	..	..	–1	19	
	37(2)	30	..	..	0	80	
	37	30	..	..	70	204	Over 30 lbs. P_2O_5 as Superphosphate.
	28–29	34	..	..	73	48	
	31(2), 32 33, 34, 35	..	16	..	–12	32	
	31	..	20	..	–14	35	Over 20 lbs. N as Am. sulphate.
	32, 33, 34	..	20	..	6	33	Do. + 5 tons F. Y. M.
	31	..	65	..	14	35	Over 20 lbs. N as Am. sulphate.
	32, 33, 34	..	65	..	–16	38	Do. + 5 tons F.Y.M.
	31	..	..	26	–78	35	Over 20 lbs. N + 20 lbs. P_2O_5 as Nicifos 22/18.
	32, 33, 34	..	..	26	–84	33	Do. + 5 tons F. Y. M.
	19–27	..	..	30	–30	61	
	31	..	..	35	–88	35	Over 20 lbs. N as Am. sulphate.
	32, 33, 34	..	..	35	–46	33	Do. + 5 tons F. Y. M.
	28	..	..	38	34	21	
	31	..	..	52	–98	35	Over 20lbs. P_2O_5 as Nicifos 22/18.
	32, 33, 34	..	..	52	–16	33	Do. + 5 tons F. Y. M.

Organic Manures.

Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre.	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response.	REMARKS.
19–27	F. Y. M. 5 tons. ..	56	118	61	
28	Dung. ..	56	–67	84	
	Torai Cake.				
21–27 25–28	280 lbs. ..	11	–17	58	
25–28	420 lbs. ..	17	129	80	
21–27	560 lbs. ..	22	364	67	
	Mahua Cake.				
21–27	280 lbs. ..	8	10	67	
25–28	480 lbs. ..	14	3	95	
21–27	560 lbs. ..	17	152	67	
25–28	720 lbs. ..	22	27	80	

TABLE VI—PUNJAB—(*contd.*)

Artificial Fertilizers. *Organic Manures.*

Station	Year 19-	Amount of artificials. lbs. per acre. N	P₂O₅	K₂O	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.	Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre.	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
Lyallpur (contd.)	25	3	18	..	–7	65	P as Bonemeal.						
	32	4	25	..	55	32	Do.						
	32	4	25	..	61	21	Do.						
	33	11	12	..	66	45	Over green manure.						
	33	11	12	..	38	39	Over green manure.						
	19–27	11	67	..	–49	61							
	31	20	20	..	116	35	For Nicifos 22/18.						
	33, 33, 34	20	20	..	33	33	Do.						
	37	30	16	..	–143	116	Over 5 tons F. Y. M.						
	19–27	57	69	..	465	76	Mixture of Bonemeal and Sodi. Nitrate over 67 lbs. Pot. sulphate.						
	31	20	..	35	42	35							
	32, 33, 34	20	..	35	4	33	Over 5 tons F. Y. M.						
	19–27	50	..	30	489	76	Over 300 lbs. Bonemeal.						
	33	..	12	31	–12	77							
	33	..	12	31	–67	70	Over green manure.						
	28	..	14	27	–44	119	Over 37 lbs. N as Am. sulphate.						
	31	..	20	26	–92	35	Over 20 lbs. N as Am. sulphate.						
	32, 33, 34	..	20	26	–81	33	Do. + 5 tons F. Y. M.						
	31	..	20	52	–62	35	Over 20 lbs. N as Am. sulphate.						
	32, 33, 34	..	20	52	–29	33	Do. + 5 tons F. Y M.						
	31(2), 32, 33, 34, 35	7	7	4	92	49							
	19–27	11	60	30	316	76	Bonemeal + Pot. Sulphate over 50 lbs. N Sodi. Nitrate.						
	31	20	20	26	33	35	Nicifos 22/18 + Pot. Sulphate.						
	32, 33 34	20	20	26	–54	33	Do.						
	31	20	20	52	18	35	Over 5 tons F. Y. M.						
	32, 33, 34	20	20	52	40	33	Over 5 tons F.Y.M.						
	28	33	14	21	122	84							
	19–27	57	69	30	439	61	Bonemeal + Sodi. Nitrate + Pot. Sulphate.						
Kote Bran Ford Estate. ** (*Lyallpur*).	36(2), 37	15	..	..	216	50							
	37	31	..	..	299	69							
	37	45	..	..	277	69							
	37	60	..	..	305	69							
	37	75	..	..	322	69							

TABLE VI.—PUNJAB—(*contd.*)

Artificial Fertilizers. *Organic Manures.*

Station.	Year 19-	Amount of artificials. lbs. per acre.			Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.	Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
		N	P_2O_5	K_2O									
*Piranwala*** (Multan).	36	17	..	..	158	122							
	36	33	..	..	310	86							
	36	..	33	..	100	122	Over 33 lbs. N, as Am. sulphate.						
	36	33	33	..	410	122							
*Brucepur***	36	16	..	..	113	38							
	36, 37	31	..	..	181	35							
Khanewal	29,30 31(2) 32(2) 33(2)	16	..	..	133	31							
	29	34	..	..	312	48							
	31, 32, 33	..	16	..	40	43							
	,,	7	7	4	45	43							
*Okara***	30	15	..	..	358	..							
	30	15	..	..	103	..	Over 15 lbs. P_2O_5 as Superphosphate.						
	33	15	..	..	375	130	Over 4 tons of Ngiht Soil.						
	31	20	..	..	118	108							
	31(4) 32(2) 33(2)	30	..	..	154	37							
	30	30	..	..	236	..							
	30	..	15	..	169	..							
	30	..	15	..	–71	..	Over 15 lbs. N as Am. sulphate.						
	30	..	15	..	–106	..	Do. with a basal dose of 4 tons Night Soil.						
	31(2) 32(2) 33(2)	..	30	..	41	53	Over 30 lbs. N as Am. sulpate.						
	30(2)	..	30	..	52	..	Do.						
	31, 32, 33	..	..	60	–37	47	Over 30 lbs. N + 30 lbs. P as Nicifos 22/18.						
	30	..	..	60	11	..	Over 30 lbs. N + 30 lbs. P as Nicifos 22/18.						
	31, 32, 33	10	10	..	247	64							
	30	10	10	..	256	..							
	33	15	15	..	269	130	Over 4 tons Night Soil.						
	30	15	15	..	282	..							
	31 (2) 32, 33	20	20	..	308	64							
	30	20	20	..	318	..							

TABLE VI.—PUNJAB—(*contd.*)

Artificial Fertilizers. *Organic Manures.*

Station	Year 19-	Amount of artificials. lbs. per acre. N	P₂O₅	K₂O	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.	Year 19-	Amount of manures per acre.	Equivalent amount of N, P, K, lbs. per acre N	P₂O₅	K₂O	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
Okara ** (contd.)	31(2), 32, 33	30	30	..	240	37									
	30(2)	30	30	..	288	..									
	31	35	35	..	260	103									
	31, 32, 33	40	40	..	327	64									
	30	40	40	..	317	..									
	31, 32, 33	60	60	..	350	64									
	30	60	60	..	384	..									
	31, 32, 33	30	96	..	304	52	Nicifos 17/48.								
	30	30	78	..	168	..	Diammonophos.								
	31, 32	30	15	..	251	82	Nicifos 22/18 + Am. Sulph.								
	31, 32, 33	..	30	60	40	47	Over 80 lbs. N. as Am. Sulph.								
	30	30	..	60	95	..	Do.								
	31, 32, 33	30	30	60	208	52									
	30	30	30	60	262	..									
Hansi	Am.	Sulphate, Sodium Nitrate.						28	F. Y. M. 5 tons ..	56	..	..	281	126	
								31, 32	F. Y. M. 5.3 tons ..	60	..	..	90	13	Years as replicates.
	27	12	..	..	94	13		28	F. Y. M. 7 tons ..	80	..	..	209	71	
	25	12	..	..	99	..	Non-replicated.								
	26, 27	15	..	..	136	15			Castor Cake.						
	25	15	..	..	59	..	Non-replicated.								
	27	22	..	..	82	63		28	1,284 lbs. ..	55	..	..	120	126	
	28, 31, 32	55	..	..	350	68		31, 32	1,300 lbs.	60	..	..	158	13	Years as replicates.
	31, 32	60	..	..	341	13	Years as replicates.	28	1,835 lbs.	80	..	..	85	71	
	28	79	..	..	611	71									
		Calcium Cyanamide.							*Mixture of Bonemeal and Organic Nitrogenous Manures.*						
	26, 27	21	..	..	–15	49									
	28	56	..	..	310	126			Bonemeal + F. Y. M.						
	31, 32	59	..	..	184	13	Years as replicates.	34	55 lbs. + 560 lbs. ..	5	11	..	60	..	Non-replicated.
	28	80	..	..	288	71		32	60 lbs. + 2814 lbs.	16	13	..	194	..	,,
	35, 36	5	26	..	–43	68	Yrs. as replicates, Bonemeal	33	60 lbs. + 4092 lbs.	62	12	..	140	..	,,
	32, 33, 34	5	26	..	77	..	Non-replicated.	35, 36	12 P + 60 N. ..	62	12	..	–24	68	Years as replicates.
									Bonemeal + Castor Cake.						
								34	55 lbs. + 384 lbs. ..	27	11	..	–37	..	Non-replicated.
								32, 33	60 lbs. + 596 lbs.	41	13	..	–61	..	,,
Sirsa	28	41	..	..	170	76	Sodi. Nitrate.		*Mixture of Artificial and Organic Manures.*						
	28	44	..	..	209	76	Am. Sulphate.	28	Sodi. Nitrate + F.Y.M.						
	28	..	20	..	–105	76			270 lbs. + 10,000 lbs.	91	..	..	166	73	
	28	..	..	53	45	76		28	Am. Sulphate + F. Y. M. 220lbs. + 10,000 lbs.	99	..	..	189	73	
								28	Pot, Sulphate + F.Y.M. 110 lbs. + 10,000 lbs.	50	..	53	100	73	
								28	Superphosphate + F.Y.M. 110 lbs. + 10,000 lbs.	50	20	20	181	173	

Experiments marked (* *) were carried out by the Imperial Chemical Industries (India) Ltd.

TABLE VII

SIND**

Artificial Fertilizers. — *Organic Manures.*

Station	Year 19-	Amount of artificials. lbs. per acre. N	P$_2$O$_5$	K$_2$O	Response. (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.	Year 19-	Amount of manures per acre.	Equivalent amount of N lbs. per acre	Response (Difference from control) lbs. of seed cotton per acre.	S. E. of response	REMARKS.
Sakrand								34, 35, 36	Compost 7.5 tons ..	118	378	65	
									Mixtures of Artificial and Organic Manures.				
								34, 35, 36	(Am. sulph. + Compost) (100 lbs. + 3.75 tons.) (21 N + 59 N) ..	80	470	58	
								36	(200 lbs. + 3.75 tons.) (42 N + 59 N) ..	101	618	112	
Berani	37	15	..	..	209	118							
	37	30	..	..	78	118							
	36	33	..	..	148	68							
	37	45	..	..	202	118							
	37	60	..	..	232	118							
	37	75	..	..	187	118							
	36	..	33	..	32	89	Over 33 lbs. N as Am. sulphate.						
	36	33	33	..	211	63							
Mirpurkhas	37	30	..	..	197	98							
	36	33	..	..	128*	42							
	37	..	16	..	522	219							
	37	..	16	..	–164	219	Over 30 lbs N as Am. Sulphate						
	37	..	33	..	–30	30	Over 33 lbs. N.						
	37	33	16	..	298	219							
	36	33	33	..	98*	42							
Denisar Estate	37	30	..	..	129	28							
	36	33	..	..	198	58							
	36	..	33	..	72	41	Over 33 lbs. N.						
	36	33	33	..	270	58							
Bodar	37	15	..	..	212	101							
	37	30	..	..	217	101							
	36	33	..	..	245	122							
	37	45	..	..	337	101							
	37	60	..	..	361	101							
	37	75	..	..	288	101							
	36	..	15	..	–170	172	Over 33 lbs. N as Am. sulphate.						
	36	33	15	..	244	172							
Nazikabad	36	33	..	..	161	70							

---

* All trials on American cotton except the one marked* which was on Sea Island.

** Carried out by Imperial Chemical Industries (India) Ltd.

APPENDIX C

TABLE I

Prices of Artificial and Organic Manures* in rupees per pound of Nitrogen at different stations, 1928–37.

	Ammonium sulphate							Farm Yard Manure							Groundnut cake		
Year	Surat	Jalgaon	Dharwar	Akola	Coimbatore	Koilpatti	Guntur	Surat	Jalgaon	Dharwar	Akola	Coimbatore	Koilpatti	Guntur	Akola	Koilpatti	Coimbatore
1928–29	..	0.400	0.391	0.490	0.414	..	0.414	0.300	0.446	0.268	0.152	0.357	0.178	0.357	..	0.559	0.670
1929–30	0.279	..	..	0.391	0.335	0.434	0.379	0.500	0.446	..	0.152	0.357	0.178	0.357	..	0.692	..
1930–31	0.340	0.410	..	0.357	0.356	0.387	0.368	0.300	0.252	..	0.152	0.357	0.178	0.268	0.368	0.718	0.500
1931–32	0.340	0.351	0.417	0.357	0.288	0.383	0.281	0.300	0.268	0.339	0.152	0.357	0.178	0.178	0.262	0.682	0.349
1932–33	0.340	0.316	0.417	0.257	0.240	0.383	0.273	0.300	0.268	0.339	0.152	0.178	0.178	0.178	0.259	0.682	0.416
1933–34	0.340	..	0.417	0.257	0.272	0.288	0.284	0.300	0.178	0.268	0.152	0.178	0.178	0.178	0.279	0.599	0.298
1934–35	0.340	..	0.385	0.257	0.268	0.288	..	0.300	0.223	0.268	0.152	0.178	0.178	0.178	0.195	0.487	0.251
1935–36	0.312	..	0.417	0.261	0.281	0.286	..	0.300	0.223	0.201	0.152	0.178	0.156	0.178	0.279	0.400	0.346
1936–37	0.312	..	0.417	0.273	0.277	0.281	0.312	0.300	0.223	0.201	0.152	0.178	0.184	0.178	0.268	0.388	0.335
1937–38	..	..	..	..	..	..	..	..	0.268	..	..	..	..	..	..	..	0.332

* Following percentage contents of nitrogen were used in calculating the prices per lb. of nitrogen :—

(1) Ammonium sulphate, 20, (2) Groundnut cake, 8, (3) Farm Yard Manure, 0.5.

APPENDIX C

TABLE II

Price of seed cotton in rupees per pound, at different stations, 1928-37.

Year	Surat	Jalgaon	Dhar-war	Akola		Coimbatore		Koilpatti		Guntur
				Verum	Roseum	Karun-ganni	Cambo-dia	Karun-ganni	Cambo-dia	
1928–29 ..	0.188	0.104	0.144	0.186	0.141	..	..	0.160	0.180	0.104
1929–30 ..	0.156	0.083	0.129	0.156	0.125	0.160	0.180	0.140	0.160	0.100
1930–31 ..	0.125	..	..	0.156	0.125	0.160	0.180	0.100	0.100	0.060
1931–32 ..	0.116	..	..	0.120	0.106	0.120	0.140	0.088	0.120	0.066
1932–33 ..	0.105	..	0.071	0.110	0.085	0.140	0.160	0.100	0.120	0.060
1933–34 ..	0.119	0.100	0.088	0.098	0.069	0.100	0.125	0.100	0.100	0.066
1934–35 ..	0.130	..	0.131	0.134	0.107	0.100	0.125	0.100	0.100	0.074
1935–36 ..	0.109	..	0.092	0.107	0.082	0.110	0.125	0.100	0.100	0.076
1936–37 .	0.131	..	0.099	0.097	0.092	0.110	0.125	0.125	0.125	0.076
1937–38 ..		.	0·084	..	..	0.110	0.125	0.068	0.100	..

सत्यमेव जयते